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AGGREGATE IMPACT VALUE (IS:2386-Part IV-1963)

Objective

For determination of the aggregate impact value of coarse aggregate, which passes 12.5 mm. IS sieve and retained on 10 mm. IS sieve.

Reference Standards

IS: 2386(Part IV)-1963 Methods of test for aggregate for concrete Part IV Mechanical Properties.

Equipment & Apparatus

- Aggregate Impact Test Machine
- Sieves (12.5mm,10mm)
- Cylindrical metal measure
- Tamping Rod
- Balance (0-10kg)
- Oven(300^0c)

Aggregate Impact Value Test Apparatus

Preparation Of Test Sample

Test sample consist of aggregate passing a 12.5mm IS sieve and retained on a 10mm IS sieve. The aggregate to be tested is dried in oven for a period of not less than 4hours.

1. The cylindrical steel cup is filled with 3 equal layers of aggregate and each layer is tamped 25 strokes by the rounded end of tamping rod and the surplus aggregate struck off, using the tamping rod as a straight edge.

2. The net weight of aggregate in the cylindrical steel cup is determined to the nearest gram (W_A) and this weight of aggregate is used for the duplicate test on the same material.
3. The cup is fixed firmly in position on the base of the machine and the whole of the test sample is placed in it and compacted by a single tamping of 25 strokes of tamping rod.
4. The hammer is raised until its lower face is 380 mm. above the upper surface of the aggregate in the cup, and allowed to fall freely onto the aggregate 15 times, each being delivered at an interval of not less than one second.
5. The crushed aggregate is removed from the cup and sieved on 2.36 mm. IS sieve until no further significant amount passes in one minute.
6. The fraction passing the sieve is weighed to an accuracy of 0.1 g (W_B)

Calculation

The ratio of the weight of fines formed to the total sample weight in each test is to be expressed as a percentage, to the first decimal place.

Aggregate impact Value = (W_B / W_A) × 100

AGGREGATE ABRASION VALUE (IS:2386-Part 4-1963)

Objective

For determination of the aggregate abrasion value of coarse aggregate.

Reference Standards

IS: 2386 (Part IV)-1963 Methods of test for aggregate for concrete Part IV Mechanical Properties.

Equipment & Apparatus

- Los Angeles machines
- Sieves (1.70mm)
- Cylindrical metal measure
- Tamping Rod
- Balance (0-10kg)
- Oven (300^0c)

The abrasive charge, depending upon the grading of the test sample as described in shall be as follows:

Grading	*Number of Spheres*	*Weight of Charge* g
A	12	5 000±25
B	11	4 584±25
C	8	3 330±20
D	6	2 500±15
E	12	5 000±25
F	12	5 000±25
G	12	5 000±25

TABLE II GRADINGS OF TEST SAMPLES

(*Clause* 5.3.3)

Sieve Size (Square Hole)		Weight in g of Test Sample for Grade						
Passing	Retained on	A	B	C	D	E	F	G
mm	mm							
80	63	—	—	—	—	2 500*	—	—
63	50	—	—	—	—	2 500*	—	—
50	40	—	—	—	—	5 000*	5 000*	—
40	25	1 250	—	—	—	—	5 000*	5 000*
25	20	1 250	—	—	—	—	—	5 000*
20	12·5	1 250	2 500	—	—	—	—	—
12·5	10	1 250	2 500	—	—	—	—	—
10	6·3	—	—	2 500	—	—	—	—
6·3	4·75	—	—	2 500	—	—	—	—
4.75	2·36	—	—	—	5 000	—	—	—

*Tolerance of ±2 percent permitted.

Preparation sample

Test sample is dried in oven for a period of four hours at a temperature of 100 to 110C.

Procedure

1. The required weight of test sample(A) is selected conforming to one of the grading mentioned in Table II of IS : 2386 (Part IV) – 1963.
2. The test sample and the abrasive charge is to be placed in the machine and rotated at a speed of 20 to 33 rev/min.
3. For grading A, B, C & D [as per Table II of IS : 2386 (Part IV)- 1963] the machine is to be rotated for 500 revolutions.
4. At the completion of the test, the material is discharged from the machine and separation of the sample is made on 1.70 mm. IS sieve.
5. The material coarser than 1.70 mm. IS sieve is washed, dried accurately weighed to the nearest gram (B).

Calculation

The difference between the original weight and the final weight of the test sample is expressed as a percentage of the original weight of the test sample.

$$Agg\,Abrasion Value = \frac{A-B}{A} \times 100$$

AGGREGATE FLAKINESS INDEX VALUE (IS: 2386-Part 1-1963)

Objective

For determination of flakiness index of coarse aggregate, where the size of the coarse aggregate are larger than 6.3mm .

Reference Standards

IS : 2386 (Part I) – 1963 – Method of test for aggregates for concrete (Part I) Particle size and shape.

Equipment & Apparatus

- Thickness gauge
- Sieves [63, 50, 40, 31.5, 25, 20, 16, 12.5, 10 & 6.3mm]
- Balance [0-10 kg]

Thickness Gauge

DIMENSIONS OF THICKNESS AND LENGTH GAUGES

Size of Aggregate		Thickness Gauge*	Length Gauge†
Passing Through IS Sieve	Retained On IS Sieve		
(1)	(2)	(3)	(4)
		mm	mm
63-mm	50-mm	33·90	—
50-mm	40-mm	27·00	81·0
40-mm	25-mm	19·50	58·5
31·5-mm	25-mm	16·95	—
25-mm	20-mm	13·50	40·5
20-mm	16-mm	10·80	32·4
16-mm	12·5-mm	8·55	25·6
12·5-mm	10-mm	6·75	20·2
10-mm	6·3-mm	4·89	14·7

*This dimension is equal to 0·6 times the mean sieve size.

†This dimension is equal to 1·8 times the mean sieve size.

Dimension of Thickness and Length Gauge

Preparation sample

Surface dry samples is used for the test. A minimum number of 200 pieces of any specified fraction is required to do the test.

Procedure

a. The sample is sieved through IS sieve specified in Table shown below.

b. A minimum of 200 pieces of each fraction is taken and weighed.

c. In order to separate flaky materials, each fraction is then gauged individually for thickness on a thickness gauge.

d. The total amount of flaky material passing the thickness gauge is weighed to an accuracy of 0.1% of the weight of sample.

Calculation

In order to calculate the flakiness index of the entire sample of aggregates, first the weight of each fraction of aggregate passing and retained on the specified set of sieves is noted (Y1, Y2, Y3, Y4…..etc). Each piece of these are tried to be passed through the slot of the specified thickness of the thickness gauge are found and weighed (y1, y2, y3, y4…etc). Then the flakiness index is the percentage of materials passed through the thickness gauge on the various thickness gauges, expressed as a percentage of the total weight of the sample gauged.

$$\text{Flakiness Index} = \frac{(y1 + y2 + y3 + \ldots)}{(Y1 + Y2 + Y3 + \ldots)}$$

AGGREGATE ELONGATION INDEX VALUE (IS: 2386-Part 1-1963)

Objective

For determination of elongation index of coarse aggregate, where the size of the coarse aggregate are larger than 6.3 mm.

Reference Standards

IS: 2386 (Part I) – 1963 – Method of test for aggregates for concrete (Part I) Particle size and shape.

Equipment & Apparatus

- Length gauge
- Sieves (63mm,50mm,40mm,31.5mm,25mm,20mm,16mm,12.5mm,10mm)
- Balance (0-10kg)
- Oven (300^0c)

Length Gauge

DIMENSIONS OF THICKNESS AND LENGTH GAUGES

Size of Aggregate		Thickness Gauge*	Length Gauge†
Passing Through IS Sieve	Retained On IS Sieve		
(1)	(2)	(3)	(4)
		mm	mm
63-mm	50-mm	33·90	—
50-mm	40-mm	27·00	81·0
40-mm	25-mm	19·50	58·5
31·5-mm	25-mm	16·95	—
25-mm	20-mm	13·50	40·5
20-mm	16-mm	10·80	32·4
16-mm	12·5-mm	8·55	25·6
12·5-mm	10-mm	6·75	20·2
10-mm	6·3-mm	4·89	14·7

*This dimension is equal to 0·6 times the mean sieve size.

†This dimension is equal to 1·8 times the mean sieve size.

Test Sample Preparation

Surface dry samples is used for the test. A minimum number of 200 pieces of any specified fraction is required to do the test.

Procedure

1. The sample is sieved through IS sieve specified in Table shown below.
   Dimension of Thickness and Length Gauge
2. A minimum of 200 pieces of each fraction is taken and weighed.
3. In order to separate elongated materials, each fraction is then gauged individually for length in the length gauge.
4. The pieces of aggregate from each fraction tested which could not pass through the specified gauge length with its long sides elongated are collected separately to find the total weight of aggregate retained on the length gauge from each fraction.
5. The total amount of elongated material retained by the length gauge is weighed to an accuracy of 0.1% of the weight of sample.

Calculation

In order to calculate the elongation index of the entire sample of aggregates, first the weight of each fraction of aggregate passing and retained on the specified set of sieves is noted (Y1, Y2, Y3, Y4…..etc). Each piece of these are tried to be passed through specified length of the gauge length with its longest side and those elongated pieces which do not pass the gauge are separated and weighed (y1, y2, y3, y4…etc). Then the elongated index is the total weight of the material retained on the various length gauges, expressed as a percentage of the total weight of the sample gauged.

$$\text{Elongation Index} = \frac{(y1 + y2 + y3 + \ldots)}{(Y1 + Y2 + Y3 + \ldots)}$$

Determining Water Content In Soil – Oven Drying Method (IS: 2386-Part II-1973)

This test is done to determine the water content in soil by oven drying method as per IS: 2720 (Part II) – 1973. The water content (w) of a soil sample is equal to the mass of water divided by the mass of solids.

Apparatus required :-

i) Thermostatically controlled oven maintained at a temperature of 110 ± 5°C

ii) Weighing balance, with an accuracy of 0.04% of the weight of the soil taken

iii) Air-tight container made of non-corrodible material with lid

iv) Tongs

PREPARATION OF SAMPLE

The soil specimen should be representative of the soil mass. The quantity of the specimen taken would depend upon the gradation and the maximum size of particles as under:

Procedure to determine Water Content In Soil By Oven Drying Method

i) Clean the container, dry it and weigh it with the lid (Weight 'W_1').

ii) Take the required quantity of the wet soil specimen in the container and weigh it with the lid (Weight 'W_2').

iii) Place the container, with its lid removed, in the oven till its weight becomes constant (Normally for 24hrs.).

iv) When the soil has dried, remove the container from the oven, using tongs.

v) Find the weight 'W_3' of the container with the lid and the dry soil sample.

Size of particles more than 90 percent passing through IS Sieve	Minimum quantity of the soil specimen to be taken for test (g)
425µm	25
2.0mm	50
4.75mm	200
9.50mm	300
19mm	500
37.5mm	1000

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REPORTING OF RESULTS

The water content

$w = [W_2-W_3] / [W_3 -W_1]*100\%$

An average of three determinations should be taken. A sample calculation is shown below

S. No.	Description	Determination No.		
		I	II	III
1	Weight of empty container (W_1) in g	20.12	20.08	20.00
2	Weight of container + Wet soil (W_2) in g	44.12	44.11	46.10
3	Weight of container + Dry soil (W_3) in g	41.18	41.16	43.01
	CALCULATION:			
1	Weight of water = W_2-W_3	2.94	2.95	3.09
2	Weight of solid = W_3-W_1	21.06	21.08	23.01
3	Water content $w = \frac{W_2-W_3}{W_3-W_1} \times 100\%$	13.96	13.99	13.43
	Average value		13.79%	

Note: *The figures given in the above table are for illustration purpose only.*

FLEXURAL STRENGTH TEST OF CONCRETE (IS: 516-1959)

Objective

To determine the Flexural Strength of Concrete, which comes into play when a road slab with inadequate sub-grade support is subjected to wheel loads and / or there are volume changes due to temperature / shrinking.

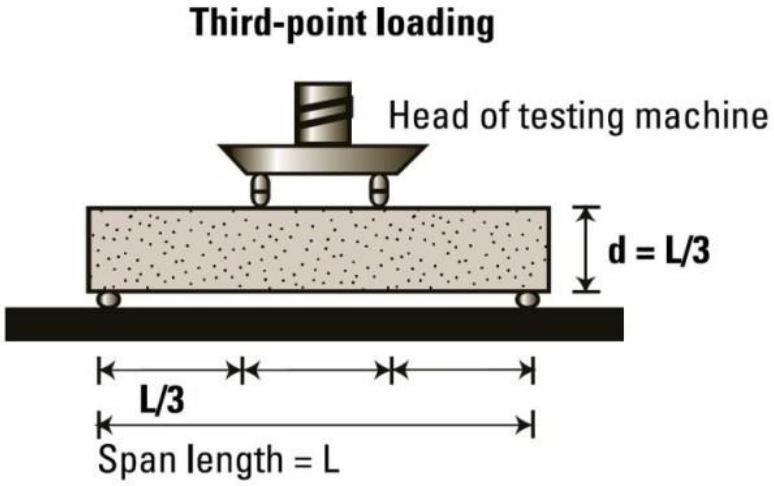
Reference Standards

IS: 516-1959 – Methods of tests for strength of concrete

Equipment & Apparatus

- **Beam mould** of size 15 x 15x 70 cm (when size of aggregate is less than 38 mm) or of size 10 x 10 x 50 cm (when size of aggregate is less than 19 mm)
- **Tamping bar** (40 cm long, weighing 2 kg and tamping section having size of 25 mm x 25 mm)
- **Flexural test machine**– The bed of the testing machine shall be provided with two steel rollers, 38 mm in diameter, on which the specimen is to be supported, and these rollers shall be so mounted that the distance from centre to centre is 60 cm for 15.0 cm specimens or 40 cm for 10.0 cm specimens. The load shall be applied through two similar rollers mounted at the third points of the supporting span that is, spaced at 20 or 13.3 cm centre to centre. The load shall be divided equally between the two loading rollers, and all rollers shall be mounted in such a manner that the load is applied axially and without subjecting the specimen to any torsional stresses or restraints.

Flexural Strength



Flexural Strength Test Arrangement

Procedure

1. Prepare the test specimen by filling the concrete into the mould in 3 layers of approximately equal thickness. Tamp each layer 35 times using the tamping bar as specified above. Tamping should be distributed uniformly over the entire crossection of the beam mould and throughout the depth of each layer.
2. Clean the bearing surfaces of the supporting and loading rollers , and remove any loose sand or other material from the surfaces of the specimen where they are to make contact with the rollers.
3. Circular rollers manufactured out of steel having cross section with diameter 38 mm will be used for providing support and loading points to the specimens. The length of the rollers shall be at least 10 mm more than the width of the test specimen. A total of four rollers shall be used, three out of which shall be capable of rotating along their own axes. The distance between the outer rollers (i.e. span) shall be **3d** and the distance between the inner rollers shall be **d**. The inner rollers shall be equally spaced between the outer rollers, such that the entire system is systematic.
4. The specimen stored in water shall be tested immediately on removal from water; whilst they are still wet. The test specimen shall be placed in the machine correctly centered with the longitudinal axis of the specimen at right angles to the rollers. For moulded specimens, the mould filling direction shall be normal to the direction of loading.
5. The load shall be applied at a rate of loading of 400 kg/min for the 15.0 cm specimens and at a rate of 180 kg/min for the 10.0 cm specimens.

Calculation

The Flexural Strength or modulus of rupture ($\mathbf{f_b}$) is given by

$\mathbf{f_b = pl/bd^2}$ (when **a** > 20.0cm for 15.0cm specimen or > 13.0cm for 10cm specimen)

or

$\mathbf{f_b = 3pa/bd^2}$ (when **a** < 20.0cm but > 17.0 for 15.0cm specimen or < 13.3 cm but > 11.0cm for 10.0cm specimen.)

Where,

a = the distance between the line of fracture and the nearer support, measured on the center line of the tensile side of the specimen

b = width of specimen (cm)

d = failure point depth (cm)

l = supported length (cm)

p = max. Load (kg)

Reports

The Flexural strength of the concrete is reported to two significant figures.

COMPRESSIVE STRENGTH TEST OF CONCRETE (IS:516-1959)

Objective

The tests are required to determine the strength of concrete and therefore its suitability for the job.

Reference Standards

IS : 516-1959 – Methods of tests for strength of concrete.

Equipment & Apparatus

- Compression testing machine (2000 KN)
- Curing tank/Accelerated curing tank
- Balance (0-10 Kg)

Compressive Strength Test on Concrete

Procedure

1. Representative samples of concrete shall be taken and used for casting cubes 15 cm x 15 cm x 15 cm
2. The concrete shall be filled into the moulds in layers approximately 5 cm deep. It would be distributed evenly and compacted either by vibration or by hand tamping. After the top layer has been compacted, the surface of concrete shall be finished level with the top of the mould using a trowel; and covered with a glass plate to prevent evaporation.
3. The specimen shall be stored at site for 24+ ½ h under damp matting or sack. After that, the samples shall be stored in clean water at $27+2^0$C; until the time of test. The ends of all cylindrical specimens that are not plane within 0.05 mm shall be capped.
4. Just prior to testing, the cylindrical specimen shall be capped with sulphur mixture comprising 3 parts sulphur to 1 part of inert filler such as fire clay.
5. Specimen shall be tested immediately on removal from water and while they are still in wet condition.
6. The bearing surface of the testing specimen shall be wiped clean and any loose material removed from the surface. In the case of cubes, the specimen shall be placed in the machine in such a manner that the load cube as cast, that is, not to the top and bottom.

7. Align the axis of the specimen with the steel platen, do not use any packing.
8. The load shall be applied slowly without shock and increased continuously at a rate of approximately 140 kg/sq.cm/min until the resistance of the specimen to the increased load breaks down and no greater load can be sustained. The maximum load applied to the specimen shall then be recorded and any unusual features noted at the time of failure brought out in the report.

Calculation

Compressive strength is calculate using the following formula

Compressive strength (kg/cm^2) = W_f / A_p

Where

W_f = Maximum applied load just before load, (kg)

A_p = Plan area of cube mould, (mm^2)

DETERMINATION OF FIELD DENSITY OF SOIL BY CORE CUTTER METHOD (IS-27270-PART-29)

Aim

To determine the field density of soil by core cutter method

Reference

IS-2720-Part-29-Determination of dry density of soil in place by the core-cutter method

Apparatus

1. Cylindrical core cutter
2. Steel rammer
3. Steel dolly
4. Balance
5. Steel rule
6. Spade or pickaxe
7. Straight edge
8. Knife

Core cutter, Dolly & Rammer

Procedure

1. Measure the height (h) and internal diameter (d) of the core cutter and apply grease to the inside of the core cutter
2. Weigh the empty core cutter (W_1)
3. Clean and level the place where density is to be determined.
4. Drive the core cutter, with a steel dolly on its top, into the soil to its full depth with the help of a steel rammer.
5. Excavate the soil around the cutter with a crow bar and gently lift the cutter without disturbing the soil in it.
6. Trim the top and bottom surfaces of the sample and clean the outside surface of the cutter.
7. Weigh the core cutter with soil (W_2)
8. Remove the soil from the core cutter, using a sample ejector and take representative soil sample from it to determine the moisture content.

Precautions

1. Core cutter method of determining the field density of soil is only suitable for fine grained soil (Silts and clay). This is because collection of undisturbed soil sample from a coarse grained soil is difficult and hence the field properties, including unit weight, cannot be maintained in a core sample
2. Core cutter should be driven into the ground till the steel dolly penetrates into the ground half way only so as to avoid compaction of the soil in the core.
3. Before lifting the core cutter, soil around the cutter should be removed to minimize the disturbances.

Observations and Calculations

Calculate wet unit weight (γ_{wet}) of the soil using the following relationship

$\gamma_{wet} = (W_2-W_1)/V$

Where,

W_1 = Empty weight of core cutter

W_2 = Weight of core cutter + soil

V = Volume of core cutter ($\pi d^2 h/4$)

D = Inner diameter of core cutter

H = Height of core cutter

FIELD DENSITY OF SOIL BY SAND REPLACEMENT METHOD (IS-2720-PART-28)

Aim

To determine the field density of soil at a given location by sand replacement method

Reference

IS-2720-Part-28-Determination of dry density of soils in place, by the sand replacement method

Apparatus

1. Sand pouring cylinder
2. Calibrating can
3. Metal tray with a central hole
4. Dry sand (passing through 600 micron sieve)
5. Balance
6. Moisture content bins
7. Glass plate
8. Metal tray
9. Scraper tool

Theory and Application

Determination of field density of cohesion less soil is not possible by core cutter method, because it is not possible to obtain a core sample. In such situation, the sand replacement method is employed to determine the unit weight. In sand replacement method, a small cylindrical pit is excavated and the weight of the soil excavated from the pit is measured. Sand whose density is known is filled into the pit. By measuring the weight of sand required to fill the pit and knowing its density the volume of pit is calculated. Knowing the weight of soil excavated from the pit and the volume of pit, the density of soil is calculated. Therefore, in this experiment there are two stages, namely

1. Calibration of sand density
2. Measurement of soil density

Sand Replacement Method

Procedure

Stage-1 (Calibration of Sand Density)

1. Measure the internal dimensions (diameter, d and height, h) of the calibrating can and compute its internal volume, $\mathbf{V_c} = \pi d^2 h/4$.
2. Fill the sand pouring cylinder (SPC) with sand with 1 cm top clearance (to avoid any spillover during operation) and find its weight ($\mathbf{W_1}$)
3. Place the SPC on a glass plate, open the slit above the cone by operating the valve and allow the sand to run down. The sand will freely run down till it fills the conical portion. When there is no further downward movement of sand in the SPC, close the slit. Measure the weight of the sand required to fill the cone. Let it be $\mathbf{W_2}$.
4. Place back this $\mathbf{W_2}$ amount of sand into the SPC, so that its weight becomes equal to $\mathbf{W_1}$ (As mentioned in point-2). Place the SPC concentrically on top of the calibrating can. Open the slit to allow the sand to run down until the sand flow stops by itself. This operation will fill the calibrating can and the conical portion of the SPC. Now close the slit and find the weight of the SPC with the remaining sand ($\mathbf{W_3}$)

Stage-2 (Measurement of Soil Density)

1. Clean and level the ground surface where the field density is to be determined
2. Place the tray with a central hole over the portion of the soil to be tested.
3. Excavate a pit into the ground, through the hole in the plate, approximately 12 cm deep (same as the height of the calibrating can). The hole in the tray will guide the diameter of the pit to be made in the ground.
4. Collect the excavated soil into the tray and weigh the soil ($\mathbf{W}$)
5. Determine the moisture content of the excavated soil.
6. Place the SPC, with sand having the latest weight of $\mathbf{W_1}$, over the pit so that the base of the cylinder covers the pit concentrically.
7. Open the slit of the SPC and allow the sand to run into the pit freely, till there is no downward movement of sand level in the SPC and then close the slit.
8. Find the weight of the SPC with the remaining sand ($\mathbf{W_4}$).

Precautions

- If for any reason it is necessary to excavate the pit to a depth other than 12 cm, the standard calibrating can should be replaced by one with an internal height same as the depth of pit to be made in the ground.
- Care should be taken in excavating the pit, so that it is not enlarged by levering, as this will result in lower density being recorded.
- No loose material should be left in the pit.
- There should be no vibrations during this test.
- It should not be forgotten to remove the tray, before placing the SPC over the pit.

Observations and Calculations

Enter all the data as per the table given below and calculate accordingly.

Sl no	Data (Calibration of Unit Weight of Sand)	Trial-1
1	Volume of the calibrating container, V (cm^3)	
2	Weight of SPC + sand, $\mathbf{W_1}$ (g)	
3	Weight of sand required to fill the conical portion on a flat surface, $\mathbf{W_2}$ (g)	
4	Weight of SPC + sand (after filling calibrating can), $\mathbf{W_3}$ (g)	
5	Weight of sand required to fill the calibrating container, $\mathbf{W_c = (W_1 - W_2 - W_3)}$ (g)	
6	Unit weight of sand, $\boldsymbol{\gamma_{sand} = (W_c)/V}$ (g/cm^3)	

Sl. No	Data (Determination of Density of Soil)	Trial-1
1	Weight of the excavated from the pit (**W**) (g)	
2	Weight of sand + SPC, before pouring, $\mathbf{W_1}$ (g)	
3	Weight of SPC after filling the hole & conical portion, $\mathbf{W_4}$ (g)	
4	Weight of sand in the pit $\mathbf{W_p = (W_1 - W_4 - W_2)}$ (g)	
5	Volume of sand required to fill the pit $\mathbf{V_p = W_p/\gamma_{sand}}$ (cm^3)	
6	Wet unit weight of the soil $\boldsymbol{\gamma_{wet} = W/V_p}$ (g/cm^3)	
7	Dry unit weight of the soil $\boldsymbol{\gamma_{dry} = \gamma_{wet}/(1+m)}$ (g/cm^3) (where '**m**' is the moisture content of soil)	

LIQUID LIMIT TEST OF SOIL USING CASAGRANDE APPARATUS (IS-2720-PART-5-1985)

Objective

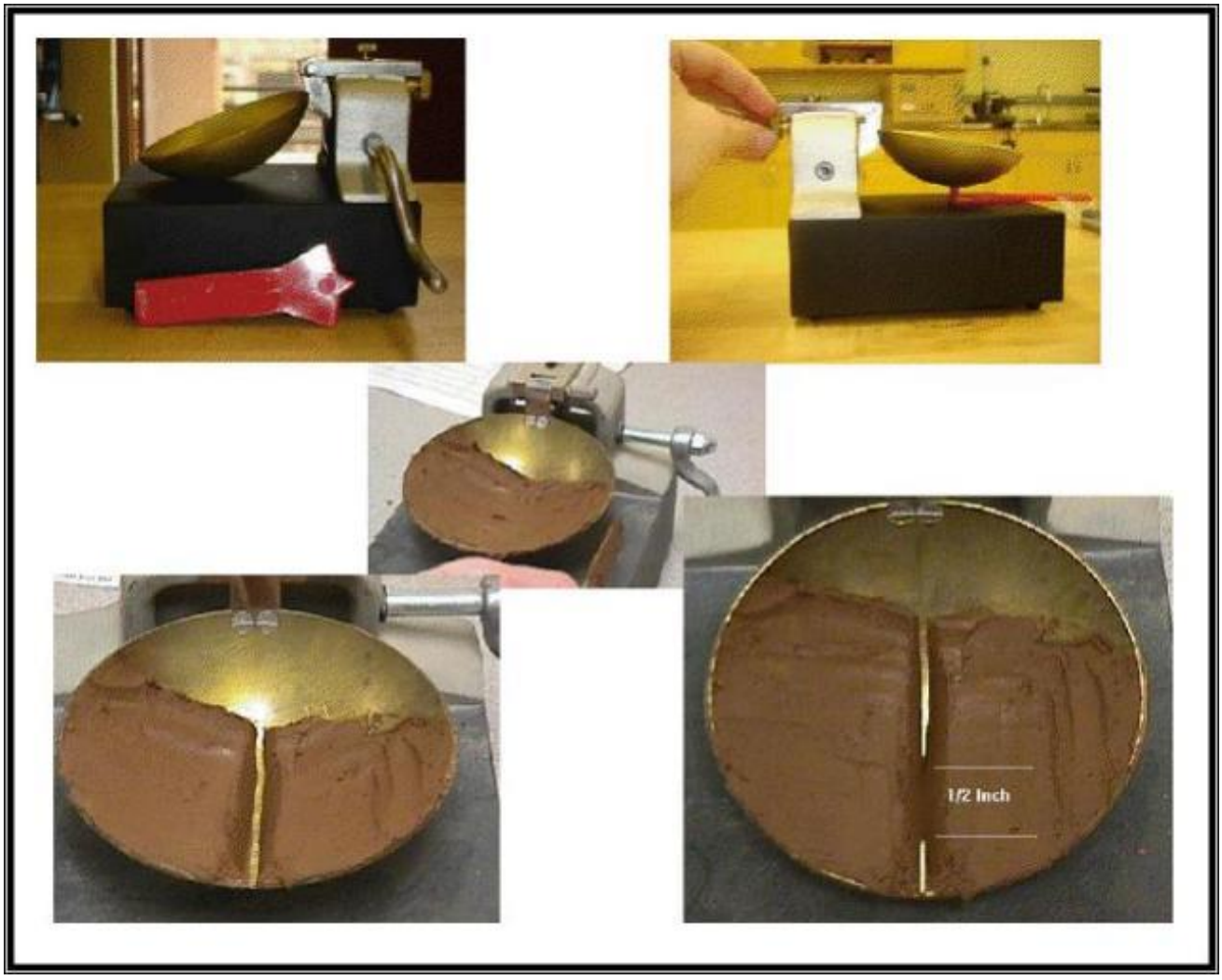
For determination of the liquid limit of soil using casagrande apparatus.

Reference Standard

IS: 2720(Part 5)-1985- Methods of test for soils: Determination of liquid and plastic limit.

Equipment & Apparatus

- Oven
- Balance (0.01g accuracy)
- Sieve [425 micron]
- Casagrande apparatus



CASAGRANDE APPARATUS

Preparation sample

After receiving the soil sample it is dried in air or in oven (maintained at a temperature of 60^0C). If clods are there in soil sample then it is broken with the help of wooden mallet. The soil passing 425 micron sieve is used in this test.

Procedure

1. About 120 gm. of air dried soil from thoroughly mixed portion of material passing 425 micron IS sieve is obtained.
2. Distilled water is mixed to the soil thus obtained in a mixing disc to form uniform paste. The paste shall have a consistency that would require 30 to 35 drops of cup to cause closer of standard groove for sufficient length.
3. A portion of the paste is placed in the cup of casagrande device and spread into portion with few strokes of spatula.
4. It is trimmed to a depth of 1 cm. at the point of maximum thickness and excess of soil is returned to the dish.
5. The soil in the cup is divided by the firm strokes of the grooving tool along the diameter through the centre line of the follower so that clean sharp groove of proper dimension is formed.
6. Then the cup is dropped by turning crank at the rate of two revolutions per second until two halves of the soil cake come in contact with each other for a length of about 12 mm. by flow only.
7. The number of blows required to cause the groove close for about 12 mm. is recorded.
8. A representative portion of soil is taken from the cup for water content determination.
9. The test is repeated with different moisture contents at least 3 times for blows between 10 and 40.

Calculation

- A '**flow curve**' is to be plotted on a semi-logarithmic graph representing water content in arithmetic scale and the number of drops on logarithmic scale.
- The flow curve is a straight line drawn as nearly as possible through four points
- The moisture content corresponding to 25 blows as read from curve is the liquid limit of that soil

Report

The liquid limit is to be reported to the nearest whole number.

PLASTIC LIMIT TEST OF SOIL (IS-2720-PART-5-1985)

Objective

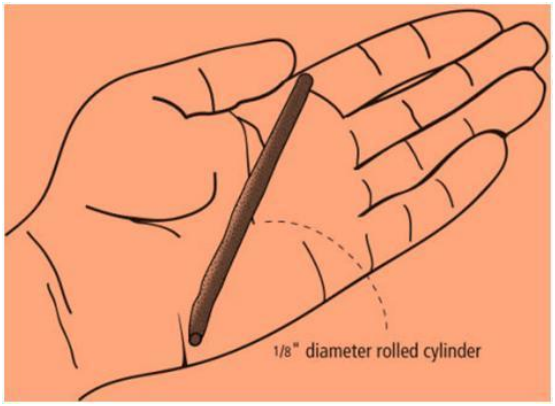
For determination of the plastic limit of soil.

Reference Standard

IS: 2720(Part 5)-1985- Methods of test for soils: Determination of liquid and plastic limit.

Equipment & Apparatus

- Oven
- Balance (0.01 g accuracy)
- Sieve [425 micron]
- Flat glass surface for rolling



Plastic Limit Test

Preparation sample

After receiving the soil sample it is dried in air or in oven (maintained at a temperature of 60^0C). If clods are there in soil sample then it is broken with the help of wooden mallet. The soil passing 425 micron sieve is used in this test.

Procedure

1. A soil sample of 20 gm. passing 425 micron IS sieve is to be taken.
2. It is to be mixed with distilled water thoroughly in the evaporating dish till the soil mass becomes plastic enough to be easily moulded with fingers.
3. It is to be allowed to season for sufficient time, to allow water to permeate throughout the soil mass.
4. 10 gms. of the above plastic mass is to be taken and is to be rolled between fingers and glass plate with just sufficient pressure to roll the mass into a thread of uniform diameter throughout its length. The rate of rolling shall be between 60 and 90 stokes per minute.
5. The rolling is to be continued till the thread becomes 3 mm. in diameter.
6. The soil is then kneaded together to a uniform mass and rolled again.
7. The process is to be continued until the thread crumbled with the diameter of 3 mm.
8. The pieces of the crumbled thread are to be collected in a air tight container for moisture content determination.

Report

The Plastic limit is to be determined for at least three portions of soil passing 425 micron IS sieve. The average of the results calculated to the nearest whole number is to be reported as the plastic limit of the soil.

LIQUID LIMIT TEST OF SOIL USING CONE PENETROMETER METHOD (IS-2720-PART-5-1985)

Objective

For determination of the liquid limit of soil using cone penetrometer.

Reference Standard

IS : 2720(Part 5)-1985- Methods of test for soils : Determination of liquid and plastic limit.

Equipment & Apparatus

- Oven
- Balance (0.01g accuracy)
- Sieve [425 micron]
- Cone penetrometer

Cone Penetrometer

Preparation sample

After receiving the soil sample it is dried in air or in oven (maintained at a temperature of 60^0C). If clods are there in soil sample then it is broken with the help of wooden mallet.

Procedure

1. About 150 gm. of air dried soil from thoroughly mixed portion of material passing 425 micron IS sieve is obtained.
2. Distilled water is mixed to the soil thus obtained in a mixing disc to form a uniform paste.
3. Then the wet soil paste is transferred to the cylindrical cup of cone penetrometer apparatus, ensuring that no air is trapped in this process.

4. Finally the wet soil is leveled up to the top of the cup and placed on the base of the cone penetrometer apparatus.
5. The penetrometer is so adjusted that the cone point just touches the surface of the soil paste in the cup and the initial ready is to be taken.
6. The vertical clamp is then released allowing the cone to penetrate into soil paste under its own weight for 5 seconds. After 5 seconds the penetration of the cone is noted to the nearest millimeter.
7. The test is repeated at least to have four sets of values of penetration in the range of 14 to 28 mm.
8. The exact moisture content of each trial is determined

Calculation

- A graph representing water content on Y – axis and the cone penetration on X – axis is prepared. A best fitting straight line is then drawn.

- The moisture content corresponding to cone penetration of 20 mm. is taken as the liquid limit of the soil.

Report

The liquid limit is to be reported to the nearest first decimal place.

Slump Test
(IS: 1199 -1959)

Suitability

This method is suitable only for the concrete of high workability.
This test is carried out with a mould called slump cone whose top diameter is 10 cm, bottom diameter is 20 cm and height is 30 cm.

Slump-Apparatus

Procedure

The test is performed in the following steps:

1. Place the slump mould on a smooth flat and non-absorbent surface.
2. Mix the dry ingredients of the concrete thoroughly till a uniform colour is obtained and then add the required quantity of water in it.
3. Place the mixed concrete in the mould to about one-fourth of its height.
4. Compact the concrete 25 times with the help of a tamping rod uniformly all over the area.
5. Place the mixed concrete in the mould to about half of its height and compact it again.
6. Similarly, place the concrete upto its three-fourth height and then up to its top. Compact each layer 25 times with the help of tamping rod uniformly. For the second and subsequent layers, the tamping rod should penetrate into underlying layer.
7. Strike off the top surface of mould with a trowel or tamping rod so that the mould is filled to its top.
8. Remove the mould immediately, ensuring its movement in vertical direction.
9. When the settlement of concrete stops, measure the subsidence of the concrete in millimeters which is the required slump of the concrete.

Recommended Slump Values for Various Concrete Works

Type of Construction	Recommend slump in mm	
	Minimum	Maximum
Pavements	25	50
Mass concrete structure	25	50
Unreinforced footings	25	75
Caissons and bridge decks	25	75
Reinforced foundation, footings and walls	50	100
Reinforced slabs and beams	30	125
Columns	75	125

Limitations of Slump Test

Following are the limitations

- Not suitable for concrete containing aggregates larger than 40 mm.
- Not suitable for concrete of dry mix.
- Not suitable for very wet concrete.
- Not reliable because slump may be of any shape.

Compaction Factor Test (IS: 1199 -1959)

Suitability

This method is adopted for determining the workability of concrete mix in laboratories. It gives fairly good results for concrete of low workability.

Procedure

The apparatus required for performing the compaction factor test is shown below.

Compaction-Factor-Test-Apparatus

1. The test is performed in the following steps:
2. Clean and dry the internal surface of the mould.
3. With the help of hand scoop, place the concrete in upper hopper A.
4. Open the trap door of hopper in order to facilitate the falling of the concrete into lower hopper B. the concrete sticking to the sides of the hopper A, should be pushed downward with the help of a steel rod.
5. Open the trap door of the hopper B and allow the concrete to fall into cylinder C.
6. Remove the surplus concrete from the top of the cylinder with the help of a trowel. Wipe and clean the outside surface of the cylinder.
7. Weigh the cylinder with partially compacted concrete nearest to 10 g.
8. Fill in the cylinder with fresh concrete in layers not exceeding 5 cm in thickness and compact each layer till 100 percent compaction is achievd.
9. Wipe off and clean the outside surface of the cylinder and weigh the cylinder with fully compacted concrete nearest to 10 g.
10. Calculate the value of compaction factor using the following formula.

Compaction factor = weight of partially compacted concrete/weight of fully compacted concrete

Recommended Values of Workability for Various Placing Conditions

Conditions	Degree	Values of Workability
Concreting of shallow sections with vibrations	Very low	20 – 10 seconds Vee-Bee time or 0.75 to 0.80 compacting factor
Concreting of lightly reinforced sections with vibrations	Low	10 – 5 seconds Vee-Bee time or 0.80 to 0.85 compacting factor
Concreting of lightly reinforced sections without vibrations or heavily reinforced sections with vibrations	Medium	5-2 seconds Vee-Bee time or 0.85 to 0.92 compacting factor or 25 – 75 mm slumps for 20 mm aggregates
Concreting of heavily reinforced sections without vibrations	High	Above 0.92 compacting factor or 75 – 125 mm slump for 20 mm aggregates.

Advantages of Compaction Factor Test

Following are the advantages:

- Suitable for testing workability in laboratories
- Suitable for concrete of low workability
- Suitable to detect the variation in workability over a wide range
- Its results are more precise and sensitive.

SILT IN FINE AGGREGATES IN THE FIELD (IS: 383 -1970)

Objective

To determine quantity of silt in fine aggregates in the field

Theory

There are two types of harmful substances preset in fine aggregates i.e. organic matter produced by decay of vegetable matter and/or clay and silt, which form coating thus preventing a good bond between cement and the aggregates. If present in large quantities, result in the increase water-cement ratio and finally affecting the strength of concrete.

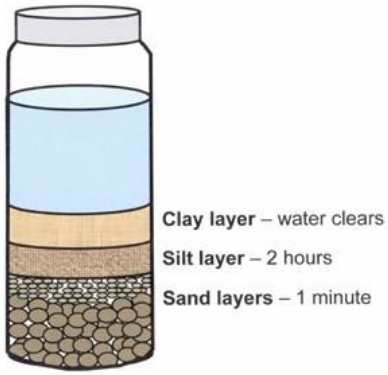
Field test is generally conducted in order to determine the volumetric percentage of silt in natural sand for percentage up to 6%, otherwise more detailed test as prescribed by standard code are required to be conducted.

Apparatus

- Measuring cylinder of 250 ml capacity.

Procedure

1. Fill 1% solution of common salt and water in the measuring cylinder up to 50 ml mark.
2. Now add sand to be tested to this solution till the level of the salt solution shows 100 ml mark.
3. Top up the level of salt solution up to 150 ml mark.
4. Shake the mixture of sand and salt solution well and keep it undisturbed for about 3 hours.
5. The silt being of finer particles than sand, will settle above the sand in a form of layer.
6. Measure the thickness of this silt layer.



Silt content in Fine Aggregates

Recording of Observation and Calculation

Sl.No.	Description	Sample Numbers		
		Sample-1	Sample-2	Sample-3
	Volume of sample, $\mathbf{V_1}$ (ml)			
	Volume of silt after 3 hours, $\mathbf{V_2}$ (ml)			
	% silt by volume $=\mathbf{(V_2/V_1)*100}$			

Note

If the average value of silt content exceeds 6% by volume, the aggregate requires washing before use.

Precautions

- Utmost care should be taken while taking sample for test

AGGREGATE CRUSHING VALUE
(IS: 2386-Part 4-1963)

Objective

For determination of the aggregate crushing value of coarse aggregate, which passes 12.5 mm. IS sieve and retained on 10 mm. IS sieve.

Reference Standard

IS: 2386 (Part IV)-1963 Methods of test for aggregate for concrete Part IV Mechanical Properties.

Equipment & Apparatus

- Steel Cylinder
- Sieves (12.5mm,10mm)
- Cylindrical metal measure
- Tamping Rod
- Balance (0-10kg)
- Oven (300^0c)
- Compression testing Machine (2000KN)

Aggregate Crushing Value Test Appratus

Preparation of sample

Test sample consist of aggregate passing a 12.5mm IS sieve and retained on a 10mm IS sieve. The aggregate to be tested is dried in oven for a period of not less than 4 hours.

Procedure

1. The cylindrical steel cup is filled with 3 equal layers of aggregate and each layer is tamped 25 strokes by the rounded end of tamping rod and the surplus aggregate struck off, using the tamping rod as a straight edge.
2. The net weight of aggregate in the cylindrical steel cup is determined to the nearest gram (W_A) and this weight of aggregate is used for the duplicate test on the same material.
3. The cup is fixed firmly in position on the base of the machine and the whole of the test sample is added in thirds, each third being subjected to 25stokes from tamping rod.
4. The surface is leveled and the plunger is inserted so that it rests horizontally on the surface. The whole assembly is then placed between the platens of testing machine and loaded at a uniform rate so as to reach a load of 40 tones in 10 minutes.
5. The load is then released and all aggregate is removed from the cup and sieved on 2.36 mm. IS sieve until no further significant amount passes in one minute.
6. The fraction passing the sieve is weighed to an accuracy of 0.1 g (W_B)

Calculation

The ratio of the weight of fines formed to the total sample weight in each test is to be expressed as a percentage, to the first decimal place.

Aggregate crushing Value $=(W_B/W_A) \times 100$

Record

The mean of the two results is reported to the nearest whole number as the aggregate crushing value of the tested material.

MOISTURE CONTENT BY THE REACTION OF CALCIUM CARBIDE WITH THE FREE WATER OF THE SOIL

(IS: 2720-PART-2)

Moisture Content Determination Using Rapid Moisture Meter

Purpose

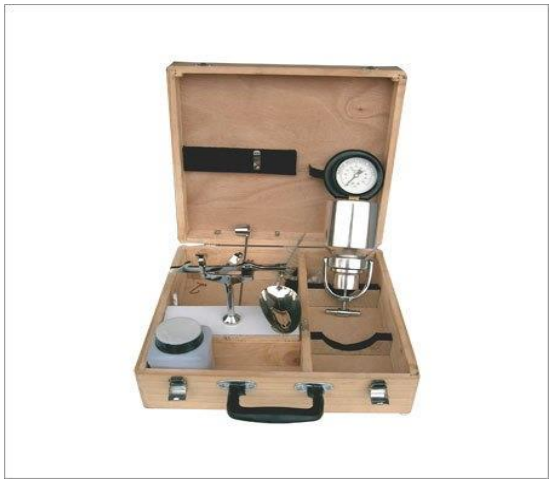
The purpose of this test is to determine the moisture content of soil quickly, without having to wait for the moisture to evaporate.

Soil Specimen

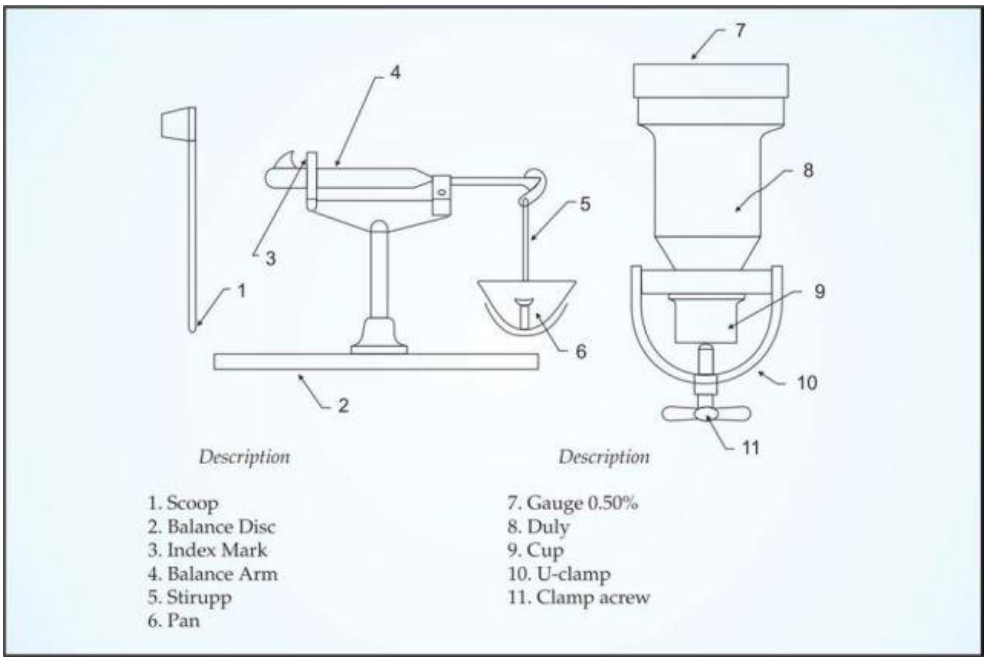
This test requires about 6 g of soil sample. Sand requires no special preparation. Coarse powders may be ground and pulverized. Cohesive and plastic soils and material are tested with addition of stee1 balls in the pressure vessels.

Equipments

1. Rapid moisture meter



Rapid Moisture Meter (Used for Water Content Test of Soil)



different parts of rapid moisture meter

Procedure

1. The apparatus required for the test includes one metallic pressure vessel with clamp for sealing cup and a gauge calibrated in percentage water. One counterpoint balance, a scoop for measuring calcium carbide and three steel balls of 12.5 mm diameter and one steel ball of 25 mm diameter.
2. Set up the balance and place the sample in the pan till the mark on the balance arm mass lines up with the index mark.
3. Unclamp the clamping screw to move the U-clamp off the cup. Lift off the cup. Clean the cup and the body.
4. Hold the body horizontally and gently deposit one level scoopful of calcium carbide halfway inside the chamber. Then lay the chamber down without disturbing the calcium carbide charge and transfer the soil weighed out as above from the pan to the cup.
5. Holding cup and chamber approximately horizontal bring them together, without disturbing sample or calcium carbide, bring the U clamp round and clamp the cup tightly into place.
6. With the gauge downwards, shake the moisture meter up and down vigorously for 5 seconds, then quickly turn it so that the gauge is upwards, give a tap to the body of the moisture meter to ensure that all the contents fall into the cup.
7. Hold the rapid moisture meter downward, again shake for 5 seconds, then turn it with gauge upwards and tap. Hold for one minute. Repeat this for a third time. Once more invert the rapid moisture meter and shake up and down to cool the gas. Turn the rapid moisture meter with the gauge upwards, and dial horizontal held at chest height when the needle comes to rest, take the reading. The readings on the meter are the percentages of water on the wet mass basis.
8. Alternatively, the three smaller steel balls can be placed in the cup along with the soil and the larger one in the body along with the absorbent and seal up the unit as usual. Hold the rapid moisture meter vertical so that the material in the cup falls into the body. Now holding the unit horizontally, rotate it for 10 seconds so that the balls are rolled round the inside circumference of the body. Rest for 20 seconds. Repeat the rotation – rest cycle until the gauge reading is constant (usually this takes 4 to 8 min). Note the reading as usual.
9. Finally release the pressure slowly (away from the operator) by opening the clamp screw and taking the cup out, empty the contents and clean the instrument with a brush.
10. Calculate the water content (W) on the dry mass from the water content (M) obtained on the wet mass basis as the reading on the rapid moisture meter, as follows:
    $W = [M/(100-M)]*100$
    Where,
    W = percent water content of the dry mass
    M = percent water content of the wet mass

Compressive strength test of cement IS 4031-Part 6

Categories: Plain and reinforced concrete

Among physical properties of cement, compressive strength is the most important property. When cement is used for important structures, compressive strength test is always carried out to ascertain quality of cement. Strength test is not made on plain cement due to excess shrinkage and cracking of plain cement paste. Following article describes step by step procedure to determine compressive strength of cement as per IS 4031 – Part 6

Materials and apparatus required :

1. Cement
2. Standard sand
3. Vibration Machine
4. Poking Rod
5. Cube Mould of size 70.6 mm X 70.6 mm X 70.6 mm
6. Gauging Trowel
7. Weigh Balance
8. Graduated glass cylinders – 200 to 250 ml capacity

Preparation of specimen and compressive strength test procedure

1. Mixing of material for each test cube shall be separately prepared. The quantities of cement,standard sand and water shall be as follows:
   Cement – 200 gms, Standard sand – 600 gms, water – (p/4+3) % of mass (cement +sand) where P = % of water required to make cement paste of standard consistency.
2. All ingredients shall be dry mixed for one minute. After that, water is gradually added till paste is formed of uniform colour. Mixing time shall be between 3-4 minutes. If uniform colour of paste is not achieved after mixing more than 4 minutes, fresh mortar shall be prepared.
3. Apply mould oil on interior surface of mould and place the mould on vibrating table. Immediately after preparing mortar as describe in point 2, place the mortar
   inside cube moulds. Rod 20 times for approximate 8 sec to ensure full compaction of mortar.

4. Further compaction shall be done by using vibrating machine.The period of vibration shall be two minutes at the specified speed of 12 000 ± 400

5.After completion of vibration, remove moulds along with base plate and finish the top surface by trowel.

6.Keep moulds filled with specimen for 24 ± 1 hr in moist environment. Remove samples from mould and immediately submerge in clean water.

7.After curing period is over, remove cubes from water and immediately place in testing machine with side facing upwards. Cubes shall be tested with out packing between steel plattens of the testing machine and cubes surface.Load shall be steadily and uniformly applied, starting from zero at a rate of 35 N/mm2/min. till failure of sample.

8.Calculate compressive strength of specimen by using following formula

compressive strength = P / A

where

P = Maximum load applied

A = cross-sectional area of test specimen

Compressive strength shall be calculated as average value of three samples. If value of individual sample is differing more than 10 % of average value, then that value shall not be considered. In that case average of other two samples shall be considered for compressive strength calculation

SOUNDNESS OF CEMENT BY LE-CHATELIERS METHOD (IS: 4031-Part 3-1988)

Overview

In the soundness test a specimen of hardened cement paste is boiled for a fixed time so that any tendency to expand is speeded up and can be detected. Soundness means the ability to resist volume expansion.

Apparatus

Measuring Instruments

NAME	CAPACITY / RANGE / SIZE	ACCURACY / LEAST COUNT
Le-chatelier apparatus	Should be made as per IS:5514	
Water bath	100^0C (min)	1^0C
Caliper	30 cm	0.5 mm
Measuring cylinder	100 ml	1 ml
Balance	100 g	1 g

Other apparatus

Glass sheets (2 nos), Enamel tray, trowel

Le chatelier Apparatus

Environmental Conditions

Temperature	27 ± 2^0 C
Humidity	65 ± 5 %

Procedure

1. Before commencing setting time test, do the consistency test to obtain the water required to give the paste normal consistency (P).
2. Prepare a paste by adding 0.78 times the water required to give a paste of standard consistency (i.e. 0.78P).
3. Lightly oil the Le-chatelier mould and place it on a lightly oiled glass sheet.
   Fill the mould with the prepared cement paste. In the process of filling the mould keep the edge of the mould gently together

4. Cover the mould with another piece of lightly oiled glass sheet, place a small weight on this covering glass sheet.
5. Submerge the whole assembly in water at a temperature of 27 ± 2^0 C and keep there for 24 hours.
6. Remove the whole assembly from water bath and measure the distance separating the indicator points to the nearest 0.5 mm (L_1).
7. Again submerge the whole assembly in water bath and bring the temperature of water bath to boiling temperature in 25 to 30 minutes. Keep it at boiling temperature for a period of 3 hours.
8. After completion of 3 hours, allow the temperature of the water bath to cool down to room temperature and remove the whole assembly from the water bath.
9. Measure the distance between the two indicator points to the nearest 0.5 mm (L_2).

Calculations

Soundness/expansion of cement = L_1-L_2

L_1=Measurement taken after 24 hours of immersion in water at a temp. of 27 ± 2^0 C

L_2=Measurement taken after 3 hours of immersion in water at boiling temperature.

Calculate the mean of two values to the nearest 0.5 mm.

Note::In the event of cement failing to comply with the specified requirements, a further test should be made from another portion of the same sample in manner described above, but after **aeration** (done by spreading out to a depth of 75 mm at a relative humidity of 50 to 80% for a total period of 7 days).

Precautions

- All the measurements should be done accurately.
- Do not apply extra pressure while filling the moulds.
- During boiling water level should not fall below the height of the mould.

Standard Specifications

Type/Name of cement	Reference Indian standard	Expansion (max.)
OPC (33)	IS:269-1989	10 mm
OPC (43)	IS:8112-1989	10 mm
OPC (53)	IS:12269-1987	10 mm
Rapid hardening	IS:8041-1990	10 mm
Low heat cement	IS:12600-1989	10 mm
Super sulphated	IS:6909-1990	5 mm
Portland pozzolana	IS:1489-1991(part 1)	10 mm
PSC	IS:455-1976	10 mm
High alumina cement	IS:6452-1989	5 mm
SRC	IS:12330-1988	10 mm
Masonry cement	IS:3466-1988	10 mm
IRS-T-40	Railway standards	5 mm

Technical Discussion

- Volume expansion in cement mortar or in cement concrete is caused by the presence of unburnt lime (CaO), dead burnt MgO and also $CaSO_4$.
- By Le-chatelier method we can only find out presence of unburnt lime (CaO).
- Presence of unburnt lime may develop cracks in the cement because of increase in volume.
- Free lime (CaO) and magnesia (MgO) are known to react with water very slowly and increase in volume considerably, which result in cracking, distortion and disintegration.

10 % fines value of coarse aggregates
IS 2386 – Part 4

An aggregates resistance to crushing is measure by the 'ten percent fines' value
10 % Fines value test apparatus

Apparatus and material required to determine 10 % fines value

The apparatus for the standard test should consist of the
1. Open-ended steel cylinder of 15 cm dia with plunger and base plate.
2. 16 mm dia straight metal tamping rod rounded at one end. Length of tamping rod should be 45-60cms.
3. Weigh balance of capacity of 3 Kg with accuracy to 1 gm
4. Set of IS Sieve-s of sizes 12.5, 10 and 2.36 mm. 5. A compression testing machine capable of applying a load of 50 tonnes and which can be operated to give a uniform rate of loading so that the maximum load in any test is reached in 10 minutes.
5. Cylindrical metal measure having following internal dimensions :
Diameter 11.5 cm
Height 18.0 cm
6. Dial gauge
7. Surface dry aggregates sample passing through 12.5 mm IS sieve and retain on 10 mm IS sieve.

Procedure to determine 10 % fines value

1. Fill cylindrical measure with aggregate sample in three equal layers, each layer should be tamped 25 times with tamping rod. Level top layer of aggregate sample with the tamping rod.
2. The weight of material comprising the test sample shall be determined (Weight A) and the same weight of sample shall be taken for the
repeat test.
To conduct two test samples,about 65Kgs of aggregates shall be required
3. The apparatus, with the test sample and plunger in position, shall then be placed in the compression testing machine. The load shall be applied at a uniform rate so as to cause a total penetration of the plunger in 10 minutes of about:

4. The load shall be released after reaching required max. penitration.The test sample should be removed and sieved through 2.36mm IS sieve. The fines passing the sieve shall be weighed,and this weight expressed as a percentage of the weight of the test sample (Recorded as A).

Penetration in mm	Type of aggregate
15	Rounded or partially rounded aggregates
20	Normal crushed aggregates,
24	Honeycombed aggregates

Calculations and recording results

The mean percentage fines from the two tests at this load shall be used in the following formula to calculate the load required to give 10 percent fines:
Load required for 10 percent fines= 14 x X / (Y + 4)
where
x = load in tonnes, and
y = mean percentage fines from two tests at x tonnes load

CBR (CALIFORNIA BEARING RATIO) TEST OF SOIL (IS-2720-PART-16-1979)

Objective

Determination of CBR of soil either in undisturbed or Remoulded condition

Reference Standards

IS: 2720(Part 16)-1973- Methods of test for soils: Laboratory determination of CBR.

Equipments / Apparatus

- Compression machine
- Proving ring, Dial gauge, Timer
- Sampling tube
- Split mould
- Vernier caliper, Balance

CBR Test Setup

Preparation sample

The test may be performed

(a) On undisturbed soil specimen

(b) On remoulded soil specimen

(a) <u>On undisturbed specimen</u>

Undisturbed specimen is obtained by fitting to the mould, the steel cutting edge of 150 mm internal diameter and pushing the mould as gentky as possible into the ground. When the mould is sufficiently full of soil, it shall be removed by under digging. The top and bottom surfaces are then trimmed flat so as to give the required length of specimen.

(b) <u>On remoulded Specimens</u>

The dry density for remoulding should be either the field density or if the subgrade is to be compacted, at the maximum dry density value obtained from the Proctor Compaction test. If it is proposed to carry out the CBR test on an unsoaked specimen, the moisture content for remoulding should be the same as the equilibrium moisture content which the soil is likely to reach subsequent to the construction of the road. If it is proposed to carry out the CBR test on a soaked specimen, the moisture content for remoulding should be at the optimum and soaked under water for 96 hours.

Soil Sample – The material used in the remoulded specimen should all pass through a 19 mm IS sieve. Allowance for larger material may be made by replacing it by an equal amount of material which passes a 19 mm sieve but is retained on a 4.75 mm IS sieve. This procedure is not satisfactory if the size of the soil particles is predominantly greater than 19 mm. The specimen may be compacted statically or dynamically.

I. <u>Compaction by Static Method</u>

The mass of the wet soil at the required moisture content to give the desired density when occupying the standard specimen volume in the mould is calculated. A batch of soil is thoroughly mixed with water to give the required water content. The correct mass of the moist soil is placed in the mould and compaction obtained by pressing in displacer disc, a filter paper being placed between the disc & soil.

II. <u>Compaction by Dynamic Method</u>

For dynamic compaction , a representative sample of soil weighing approximately 4.5 kg or more for fine grained soils and 5.5 kg or more for granular soil shall be taken and mixed thoroughly with water. If the soil is to be compacted to the maximum dry density at the optimum water content determined in accordance with light compaction or heavy compaction, the exact mass of soil required is to be taken and the necessary quantity of water added so that the water content of soil sample is equal to the determined optimum water content. The mould with extension collar attached is clamped to the base plate. The spacer disc is inserted over the base plate and a disc of coarse filter paper placed on the top of the spacer disc. The soil water mixture is compacted into the mould in accordance with the methods specified in light compaction test or heavy compaction test.

Procedure

1. The mould containing the specimen with the base plate in position but the top face exposed is placed on the lower plate of the testing machine.
2. Surcharge weights, sufficient to produce an intensity of loading equal to the weight of the base material and pavement is placed on the specimen.
3. To prevent upheaval of soil into the hole of the surcharge weights, 2.5 kg annular weight is placed on the soil surface prior to seating the penetration plunger after which the remainder of the surcharge weight is placed.
4. The plunger is to be seated under a load of 4 kg so that full contact is established between the surface of the specimen and the plunger.
5. The stress and strain gauges are then set to zero. Load is applied to the penetration plunger so that the penetration is approximately 1.25 mm per minute.
6. Readings of the load are taken at penetrations of 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 4.0, 5.0, 7.5, 10.0 and 12.5 mm.
7. The plunger is then raised and the mould detached from the loading equipment.

Calculation

Load-Penetration curve:

The load penetration curve is plotted taking penetration value on x-axis and Load values on Y-axis. Corresponding to the penetration value at which the CBR is desired, corrected load value is taken from the load-penetration curve and the CBR calculated as follows

California bearing ratio = (P_T/P_S)x100

Where

P_T = Corrected unit (or total) test load corresponding to the chosen penetration curve, and

P_S = Unit(or total) standard load for the same depth of penetration as for P_S taken from standard code.

Report

The CBR values are usually calculated for penetration of 2.5 mm and 5 mm. The CBR value is reported correct to the first decimal place.

CBR test Data - Observations & Calculations

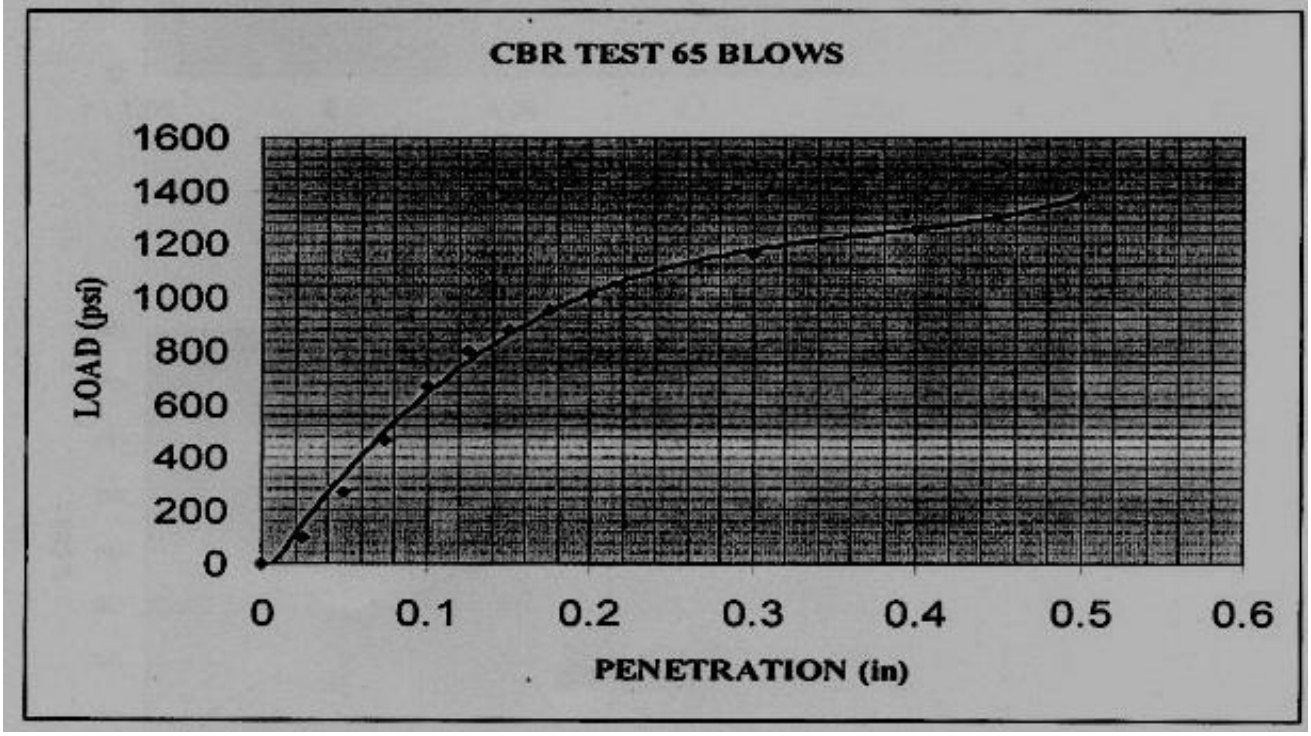
CBR TEST DATA

PENETRATION (in)	PROVING RING DIAL READING	PISTON LOAD (lb)	AREA OF PISTON (in^2)	PENETRATION STRESS (psi)
0	0	0	3	0
0.025	14.25	290.83	3	96.94
0.05	39.6	808.2	3	269.4
0.075	68.2	1391.9	3	463.97
0.1	98.06	2001.31	3 ,	667.1
0.125	117.8	2404.18	3	801.39
0.15	129.4	2640.32	3	880.11
0.175	139.6	2849.1	3	949.7
0.2	148.7	3034.82	3	1011.61
0.3	170.7	3483.82	3	1161.27
0.4	183.8	3751.18	3,	1250.39
0-5	202.2	4126.71	3	1375.57

SWELL DATA

Swell after 4 days = 0.395 mm

Height of specimen = 116.43 mm% Swell = (0.395/116.43) x 100 = 0.34 %



TEST REPORT

Data known from Modified Proctor test;

Maximum dry density = 2.204 gm /cc

O.M.C = 8 %

DRY DENSITY AND CBR DATA FOR 10 BLOWS

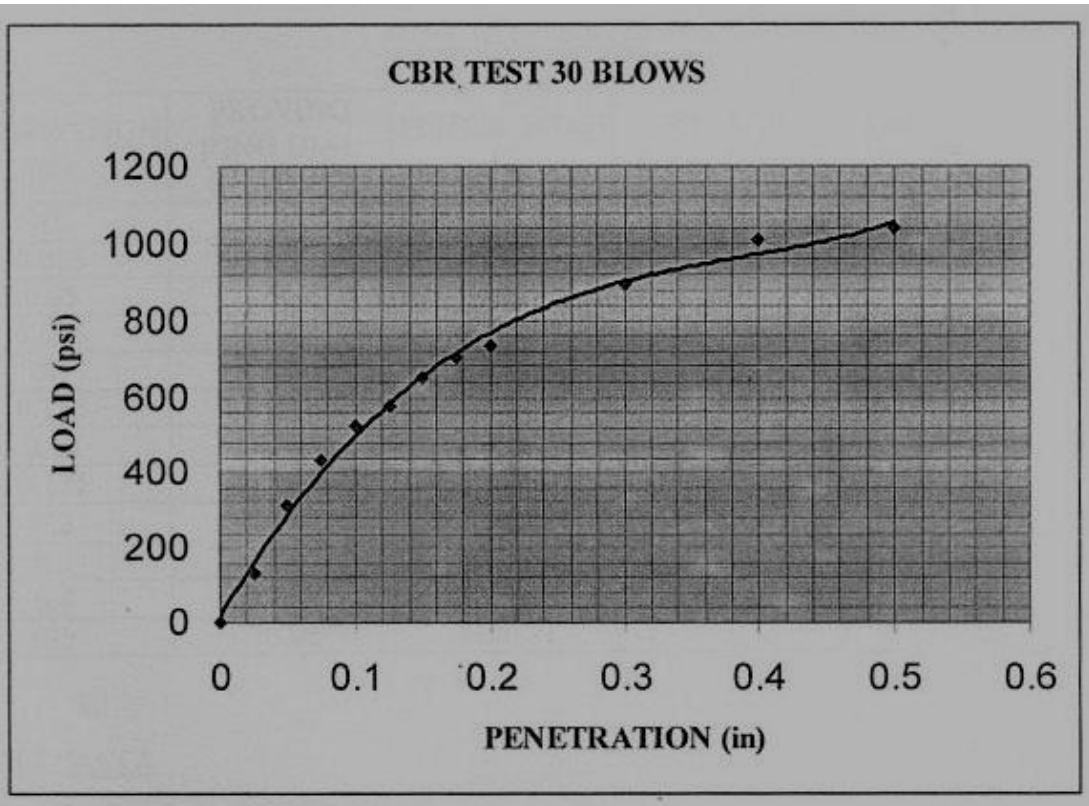
MOISTURE CONTENT		DRY DENSITY	
Container #	B 10	Weight of the mould (g)	7383
Weight of Container (g)	95.5	Wt.of mould + Compacted soil (g)	11842
Wt. of cont + Wet soil (g)	888.6	Volume of the mould cm^3	2110
Wt. Of cont + Dry soil (g)	832.4	Bulk Unit Wt. (g/cc)	2.11
Moisture Content (%)	7.63	Dry Unit Wt. (g/cc)	1.96

CBR TEST DATA

PENETRATION (in)	PROVING RING DIAL READING	PISTON LOAD (lb)	AREA OF PISTON (in^2)	PENETRATION STRESS (psi)
0	0	0	3	0
0.025	5.5	112.25	3	37.42
0.05	11	225.52	3	75.17
0.075	14.4	293.07	3	97.69
0.1	17	346.95	3	115.65
0.125	19.8	404.1	3	134.7
0.15	22	449	3	149.67
0.175	23.8	485.74	3	161.91
0.2	24.7	504.1	3	168.03
0.3	30.2	616.35	3	205.45
0.4	32	653.09	3	217.7
0.5	35	714.32	3	238.11

5. Graphs

5.1 Graph of Penetration vs Loading in CBR Test



From Graph,

CBR at 0.1" = (525/1000) x 100 = 52.5%

CBR at 0.2" = (770/1500) x 100 = 51.33%

So CBR = 52.5 %

DRY DENSITY AND CBR DATA FOR 65 BLOWS

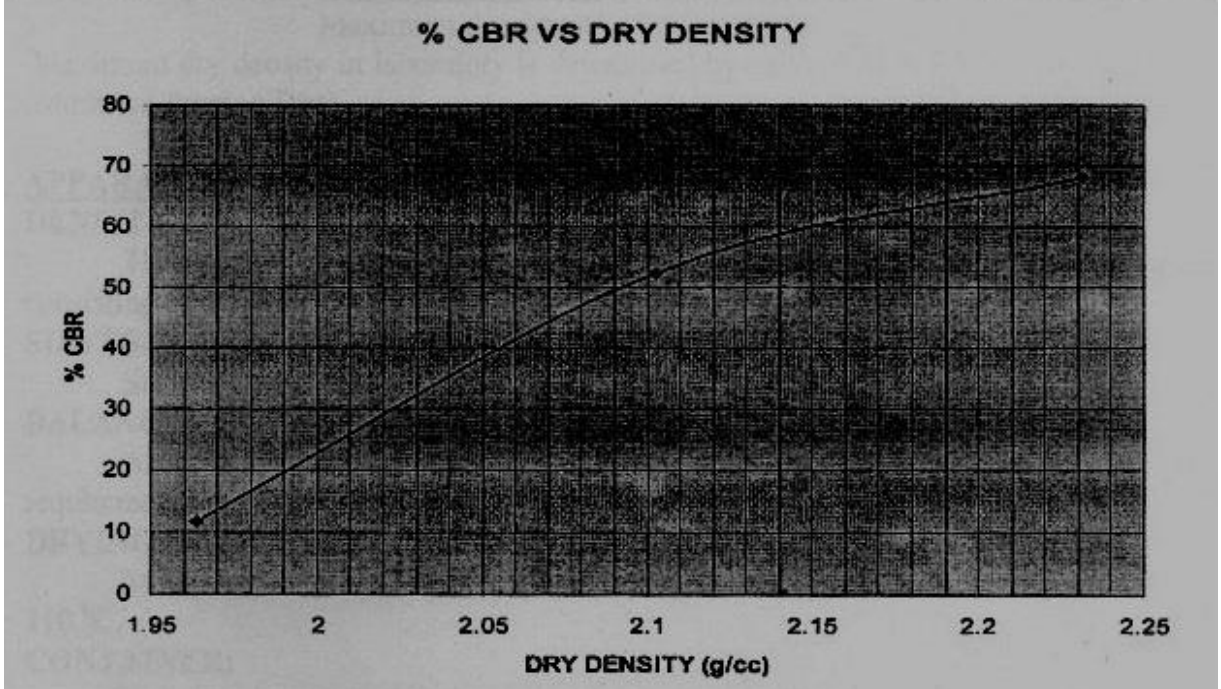
MOISTURE CONTENT		DRY DENSITY	
Container #	B 65	Wt; Of mould (g)	7415
Weight of Cont; (g)	93.7	Wt; Of mould + Compacted soil (g)	12480
Wt; Of cont; + Wet soil (g)	860.6	Volume of mould (cm^3)	2110
Wt; Of cont + Dry soil (g)	806.3	Bulk Unit Wt; (g / cc)	2.4
Moisture Content (%)	7.62	Dry Unit Wt; (g / cc)	2.231

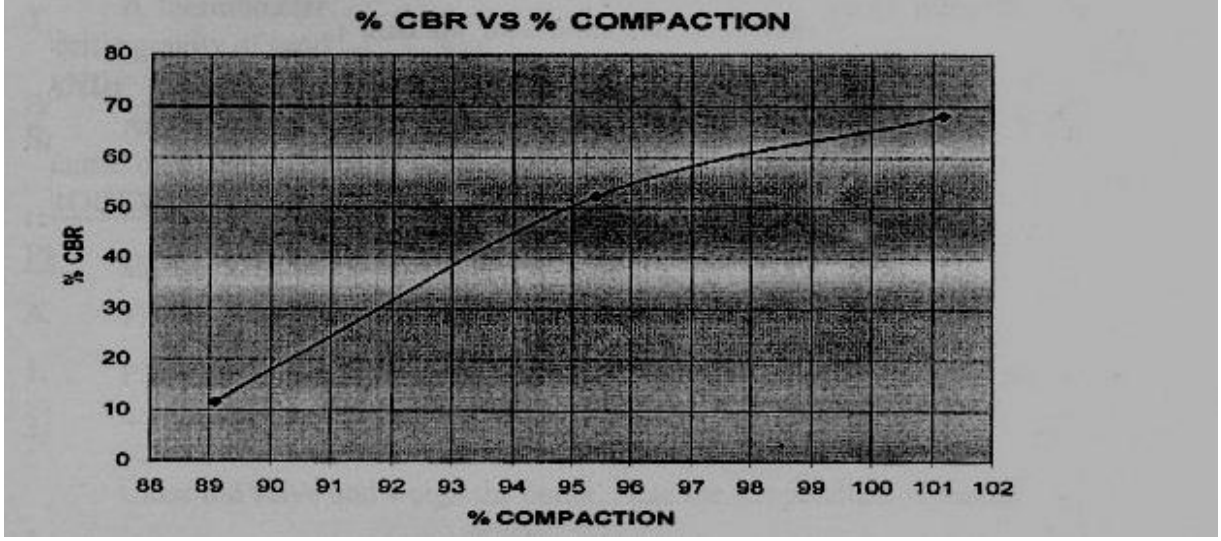
5.2 Graph of CBR vs % Percent Compaction Graph

From Graph,
CBR at 0.1" = (680/1000) x 100 = 68%
CBR at 0.2" = (1020/1500) x 100 = 68%
CBR = 68 %

DRY DENSITY AND % COMPACTION VS % CBR GRAPH

DRY DENSITY (g/cc)	% COMPACTION	CBR %
1.964	89.1	11.5
2.103	95.4	52.5
2.231	101.2	68





CBR VALUE USING DCPT RESULT ON SITE (Dynamic Cone Penetration Test)

Dynamic cone penetration test or DCPT is a quick, simple and low cost test which is extensively used by many agencies around the globe to measure the strength of compacted material of unbound granular and sub grade layers with reasonable accuracy.

Now a days DCPT is commonly used during construction for the following purposes.

- To control quality of construction
- To determine in situ CBR value
- To evaluate quality of flexible pavement

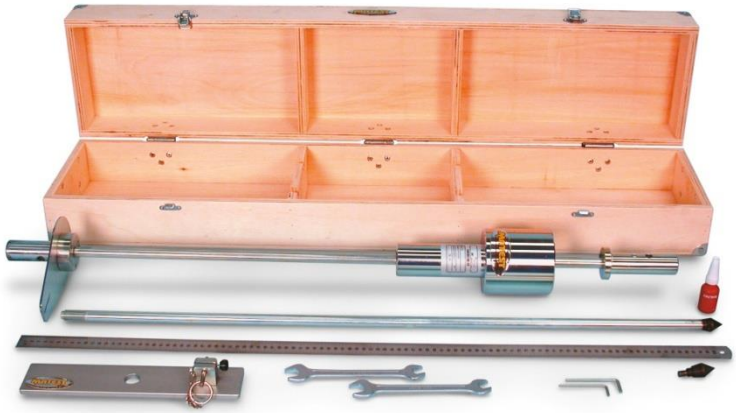
Principle of DCPT

The basic principle involved in the operation of this apparatus is the measuring of the resistance offered by the pavement layers to the penetration of a standard cone with a diameter of 20 mm (with 60^0 apex angle) driven by an 8 kg hammer freely falling through a height of 575 mm. the amount of penetration (in mm) of the cone is generally reported in terms of the average penetration per blow, **$DCPI_{60}$** (mm/blow).

Note: Greater the value of $DCPI_{60}$ indicates a softer material and vice versa.

Calculation of CBR Value from DCPT Result

Follow the below mentioned step by step procedure to calculate CBR value using DCPT result. To get a clear understanding of the calculation, an example is also given at the end of the procedure.



Dynamic Cone Penetration Test

Procedure

1. Record the initial reading on the dynamic cone penetrometer scale.
2. Calculate the value of penetration (in mm) for each blow by subtracting the previous recorded reading (i.e. reading on scale) from the current reading.
3. Calculate the cumulative depth of penetration (in mm) for each blow by adding all the previous individual depth of penetrations.
4. Draw a chart using the data of cumulative depth of penetration and number of blows.(See Fig-1)
5. This step is about identifying the depth of each layer. Identify the slope change of the penetration curve. Every change in slope represents a change in layer type.
6. After identifying each slope change, calculate the average penetration/blow for each slope change and calculate the thickness of each layer.
7. Use the following equation and determine the corresponding CBR value of each layer.

$\log_{10}CBR = 2.48 – 1.057 \log_{10}(DCPI_{60})$

To know the variation of the CBR value across the depth, draw another semi-log chart with CBR values on logarithmic scale as abscissa (x axis) and depth of penetration on ordinary scale as ordinate (y axis). (See Fig-2).

Example Calculation of CBR value

No. of blows	DCP scale reading (cm)	$DCPI_{60}$ pen/blow (mm)	Cumulative penetration (mm)	CBR value (%)	Cumulative penetration (cm)	Layer thickness (mm)	Avg CBR (%)
0	9.5	0	0	0	0	73	44.9
1	10.1	6	6	45.4	0.6		
2	10.7	6	12	45.4	1.2		
3	11.3	6	18	45.4	1.8		
4	11.9	6	24	45.4	2.4		
5	12.5	6	30	45.4	3		
6	13.1	6	36	45.4	3.6		
7	13.7	6	42	45.4	4.2		
8	14.3	6	48	45.4	4.8		
9	14.9	6	54	45.4	5.4		
10	15.5	6	60	45.4	6		
11	16.1	6	66	45.4	6.6		
12	16.8	7	73	38.6	7.3		
13	19	22	95	11.5	9.5	178	11.4
14	21.3	23	118	11.0	11.8		
15	23.5	22	140	11.5	14		
16	25.8	23	163	11.0	16.3		
17	27.8	20	183	12.7	18.3		
18	30	22	205	11.5	20.5		
19	32.3	23	228	11.0	22.8		
20	34.6	23	251	11.0	25.1		
21	38.2	36	287	6.8	28.7	646	6.9
22	41.8	36	323	6.8	32.3		
23	45.4	36	359	6.8	35.9		
24	49.0	36	395	6.8	39.5		
25	52.6	36	431	6.8	43.1		
26	56.1	35	466	7.0	46.6		
27	59.8	37	503	6.6	50.3		
28	63.4	36	539	6.8	53.9		
29	66.9	35	574	7.0	57.4		
30	70.5	36	610	6.8	61		
31	74.1	36	646	6.8	64.6		
32	77.7	36	682	6.8	68.2		
33	81.3	36	718	6.8	71.8		
34	84.8	35	753	7.0	75.3		
35	88.4	36	789	6.8	78.9		
36	92	36	825	6.8	82.5		
37	95.6	36	861	6.8	86.1		
38	99.2	36	897	6.8	89.7		

Note:

- In the example given above the initial reading is 9.5.
- There exist many equations to derive CBR value from DCPT result. The equation that we have used is commonly used. If you want you can use any other equations.

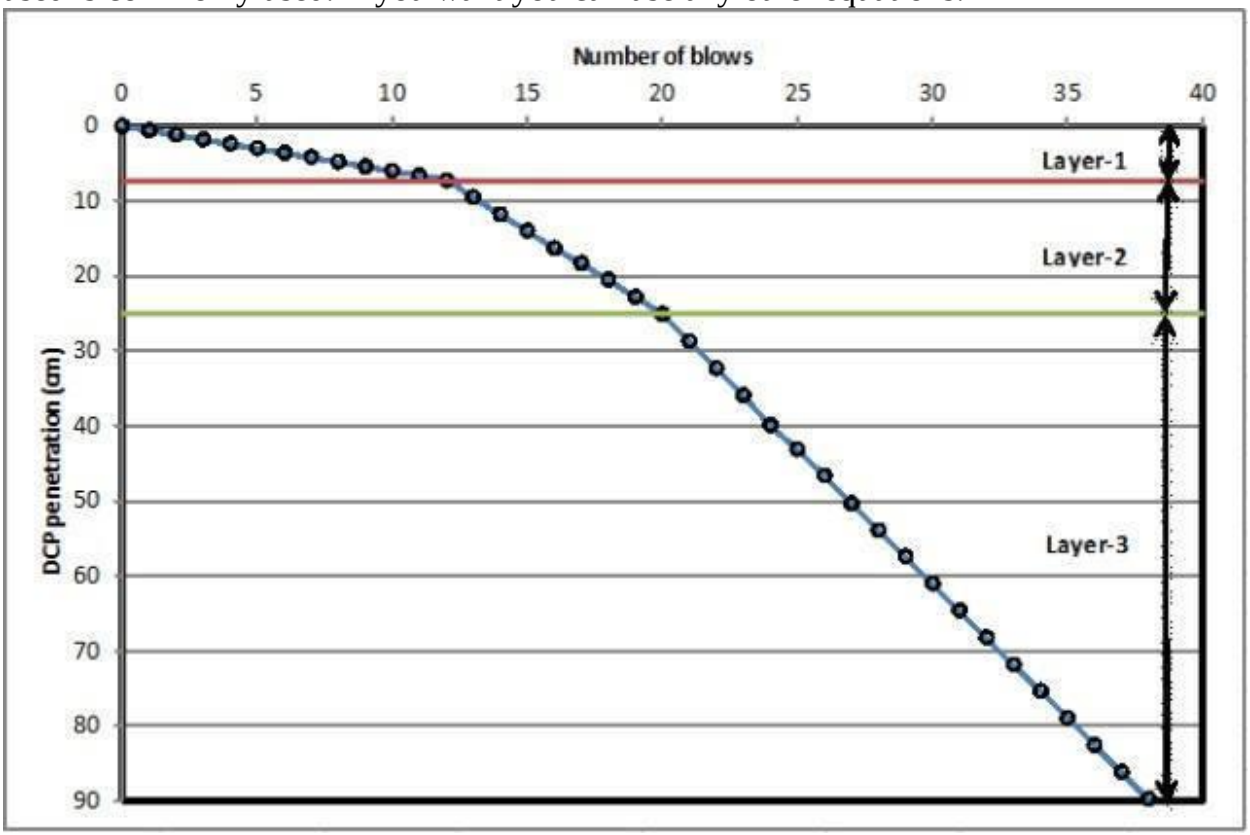


Fig-1 DCP chart

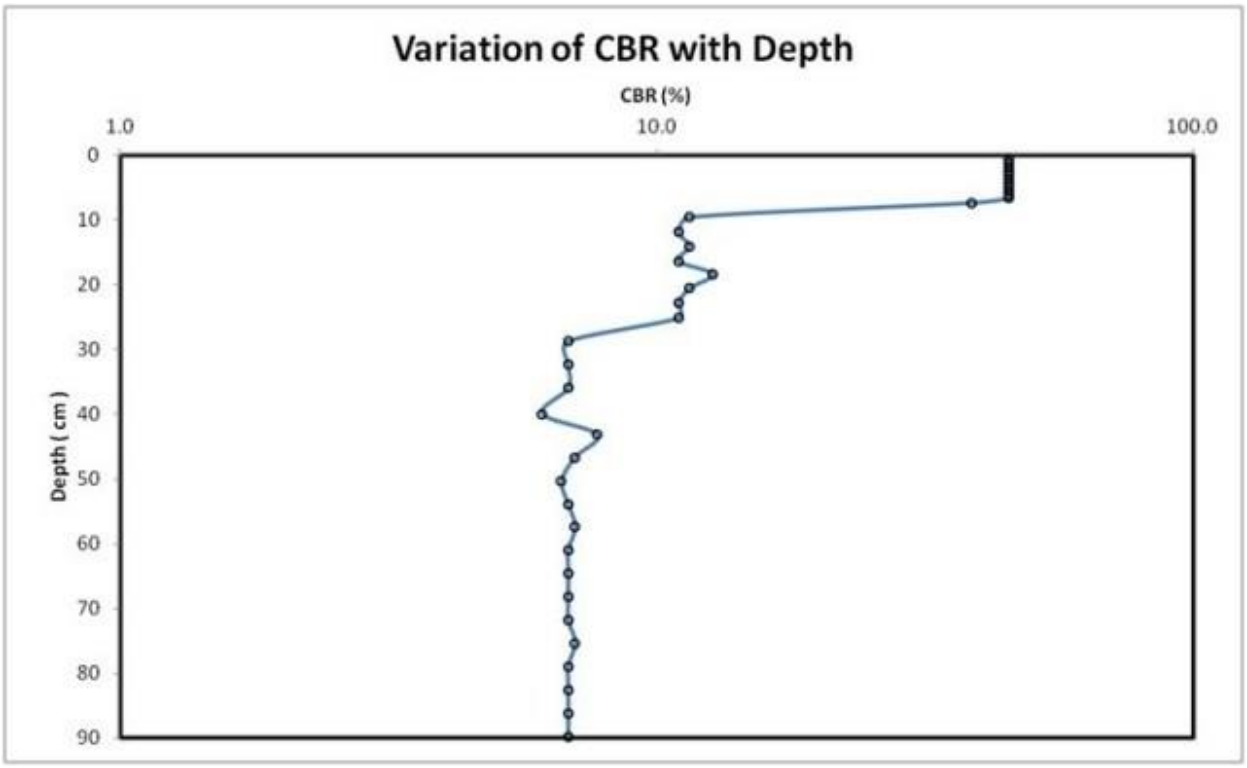


Fig-2 Variation of CBR with De

Maximum Dry Density Optimum Moisture Content Of Soil (IS: 2720 (Part 8) – 1983)

This test is done to determine the maximum dry density and the optimum moisture content of soil using heavy compaction as per IS: 2720 (Part 8) – 1983.The apparatus used is

i) Cylindrical metal mould – it should be either of 100mm dia. and 1000cc volume or 150mm dia. and 2250cc volume and should conform to IS: 10074 – 1982.

ii) Balances – one of 10kg capacity, sensitive to 1g and the other of 200g capacity, sensitive to 0.01g

iii) Oven – thermostatically controlled with an interior of noncorroding material to maintain temperature between 105 and 110ºC

iv) Steel straightedge – 30cm long

v) IS Sieves of sizes – 4.75mm, 19mm and 37.5mm

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PREPARATION OF SAMPLE

A representative portion of air-dried soil material, large enough to provide about 6kg of material passing through a 19mm IS Sieve (for soils not susceptible to crushing during compaction) or about 15kg of material passing through a 19mm IS Sieve (for soils susceptible to crushing during compaction), should be taken. This portion should be sieved through a 19mm IS Sieve and the coarse fraction rejected after its proportion of the total sample has been recorded. Aggregations of particles should be broken down so that if the sample was sieved through a 4.75mm IS Sieve, only separated individual particles would be retained.

Maximum Dry Density and the Optimum Moisture Content of Soil

A) Soil not susceptible to crushing during compaction –

i) A 5kg sample of air-dried soil passing through the 19mm IS Sieve should be taken. The sample should be mixed thoroughly with a suitable amount of water depending on the soil type (for sandy and gravelly soil – 3 to 5% and for cohesive soil – 12 to 16% below the plastic limit). The soil sample should be stored in a sealed container for a minimum period of 16hrs.

ii) The mould of 1000cc capacity with base plate attached, should be weighed to the nearest 1g (W_1). The mould should be placed on a solid base, such as a concrete floor or plinth and the moist soil should be compacted into the mould, with the extension attached, in five layers of approximately equal mass, each layer being given 25 blows from the 4.9kg rammer dropped from a height of 450mm above the soil. The blows should be distributed uniformly over the surface of each layer. The amount of soil used should be sufficient to fill the mould, leaving not more than about 6mm to be struck off when the extension is removed. The extension should be removed and the compacted soil should be levelled off carefully to the top of the mould by means of the straight edge.The mould and soil should then be weighed to the nearest gram (W_2).

iii) The compacted soil specimen should be removed from the mould and placed onto the mixing tray. The water content (w) of a representative sample of the specimen should be determined.

iv) The remaining soil specimen should be broken up, rubbed through 19mm IS Sieve and then mixed with the remaining original sample. Suitable increments of water should be added successively and mixed into the sample, and the above operations i.e. ii) to iv) should be repeated for each increment of water added. The total number of determinations made should be at least five and the moisture contents should be such that the optimum moisture content at which the maximum dry density occurs, lies within that range.

B) Soil susceptible to crushing during compaction –

Five or more 2.5kg samples of air-dried soil passing through the 19mm IS Sieve, should be taken. The samples should each be mixed thoroughly with different amounts of water and stored in a sealed container as mentioned in Part A)

C) Compaction in large size mould –

For compacting soil containing coarse material upto 37.5mm size, the 2250cc mould should be used. A sample weighing about 30kg and passing through the 37.5mm IS Sieve is used for the test. Soil is compacted in five layers, each layer being given 55 blows of the 4.9kg rammer. The rest of the procedure is same as above.

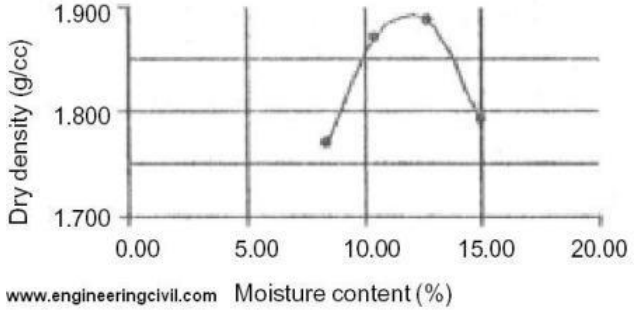
REPORTING OF RESULTS

Bulk density Y(gamma) in g/cc of each compacted specimen should be calculated from the equation,

$Y(gamma) = (W_2-W_1)/ V$ where, V = volume in cc of the mould. The dry density Yd in g/cc

$Yd = 100Y/(100+w)$

The dry densities, Yd obtained in a series of determinations should be plotted against the corresponding moisture contents,w. A smooth curve should be drawn through the resulting points and the position of the maximum on the curve should be determined. A sample graph is shown below:



The dry density in g/cc corresponding to the maximum point on the moisture content/dry density curve should be reported as the maximum dry density to the nearest 0.01. The percentage moisture content corresponding to the maximum dry density on the moisture content/dry density curve should be reported as the optimum moisture content and quoted to the nearest 0.2 for values below 5 percent, to the nearest 0.5 for values from 5 to 10 percent and to the nearest whole number for values exceeding 10 percent

PLATE LOAD TEST OF SOIL ON SITE
BS 1377 Part 9: 1990

Objective

To perform plate load test to obtain a load-settlement curve of a soil at a particular depth so as to estimate the ultimate bearing capacity a foundation.

Apparatus

1. Test plate of square size (300 mm or 450 mm or 600 mm or 750 mm)
2. Hydraulic jack (50 T capacity)
3. Hydraulic pump (50 T capacity)
4. Pressure gauge (to read 50 T load with a sensitivity of 0.5 T)
5. Proving ring or load cell (50 T capacity)
6. 4 no of dial gauges (with sensitivity of 0.01 mm and a travel of 50 mm)
7. Loading columns
8. Dial gauge supporting channels
9. Dial gauge stands
10. Magnetic bases for dial gauges
11. Loading platform equipment (girders, plates, sand bags etc) or Truss with anchor rods
12. Plumbob
13. Sprit level
14. Tripod (to erect the platform or truss frame)
15. Pulley block (to lift the girders or truss frame)

Procedure

1. Excavate the test pit. The test pit size should be 5 times the size of test plate (B_p) and depth equal to the depth of foundation.
2. The loading platform should be erected over the test pit such that, the vertical line drawn through the center of gravity of the load passes through the centroid of the base of the test pit. This can be achieved by positioning the reaction girder (truss) with the help of the plum bob and spirit level. The load over the platform should be at least 50% more than the anticipated load to be transferred on the plate. This will ensure the safety of the platform for any small shift of the CG of the loading platform from the vertical axis of the pit.
3. Position the test plate centrally at the base of the pit. Ensure that the ground surface below the test plate is perfectly horizontal and level so that no stress concentration takes place below the plate during loading. If the ground surface is slightly uneven a thin layer of sand is spread underneath the test plate.
4. Position the hydraulic jack over the plate so that when hydraulic pressure is built up the jack pushes against the loading platform. If require place a loading column between the test plate and the jack to ensure the jack reach the loading platform.
5. Position minimum of two dial gauges diagonally at the corners (preferably 4 at all corners of the test plate) to record its settlement of the plate. The dial gauges should be supported carefully over a stable base which does not settle with the plate. This can be achieved by placing two cross beams at ground level over which the dial gauges are supported with the help of magnetic bases. The settlement of the plate is transmitted to the dial gauges through dial gauge stands.
6. The dial gauges should be positioned such that the plunger of the dial gauges is at its beginning of rebound (i.e. the plunger is initially pushed up) so that it will get released as the plate settles and the reading changes and the difference in reading provided the settlement of the plate.(See fig-1 for plate load setup)
7. The load is applied on the plate by pumping the hydraulic pressure into the jack. The upward movement of the plunger of the jack tries to push the loading platform up. Since the pressure built up in the jack (say 1 or 2 T) is much less than the load on the platform, the pressure in the jack will push the test plate down by taking the loading platform (say 30 to 40 T) as rigid support. This is a case similar to the expansion of a system between two supports. Due to the expansion the weaker support (ground) yields.
8. Apply a seating load of 0.7 T/m^2 which is released before the actual loading is started.
9. Note the initial readings of the dial gauges.
10. The load is applied through the hydraulic jack in convenient increments. The load increments may be one fifth of the expected safe bearing capacity or one-tenth of the ultimate bearing capacity or any other smaller loads. The applied load is read either from the pressure gauge fitted to the hydraulic pump or from the proving ring fixed between the jack and the reaction platform.
11. Settlement of the plate is observed from the dial gauge readings. Settlement should be observed for each increment of load after 1, 4, 10, 20, 40 and 60 minutes and thereafter at hourly interval until the rate of settlement becomes less than about 0.02 mm per hour. Enter the readings in the tabular form. (See fig-2)
12. After completing the recording of settlement readings under a load, the next load increment is applied and the dial gauges readings are noted under the new load.
13. The loading increments and the recording of the settlements under each load are continued until the maximum load is reached. The maximum load that is to be applied corresponds to 1.5 times the estimated ultimate load or to 3 times the proposed allowable bearing pressure.

Observations and Calculations

The load intensity and settlement observation of the plate load test are plotted. The figure shown below (Fig-3) shows a set of typical load settlement curves. The ultimate bearing capacity is taken as the load at which the plate starts sinking at a rapid rate, i.e. when the curve drops down to a vertical line. From figure 3 it can be observed that in dense sand or stiff clays the failure is not pronounced. In such cases a plot of load and settlement, both being taken in logarithmic scales, gives two straight lines. The intersection of these lines is taken as the ultimate bearing capacity of soil (see fig.4).

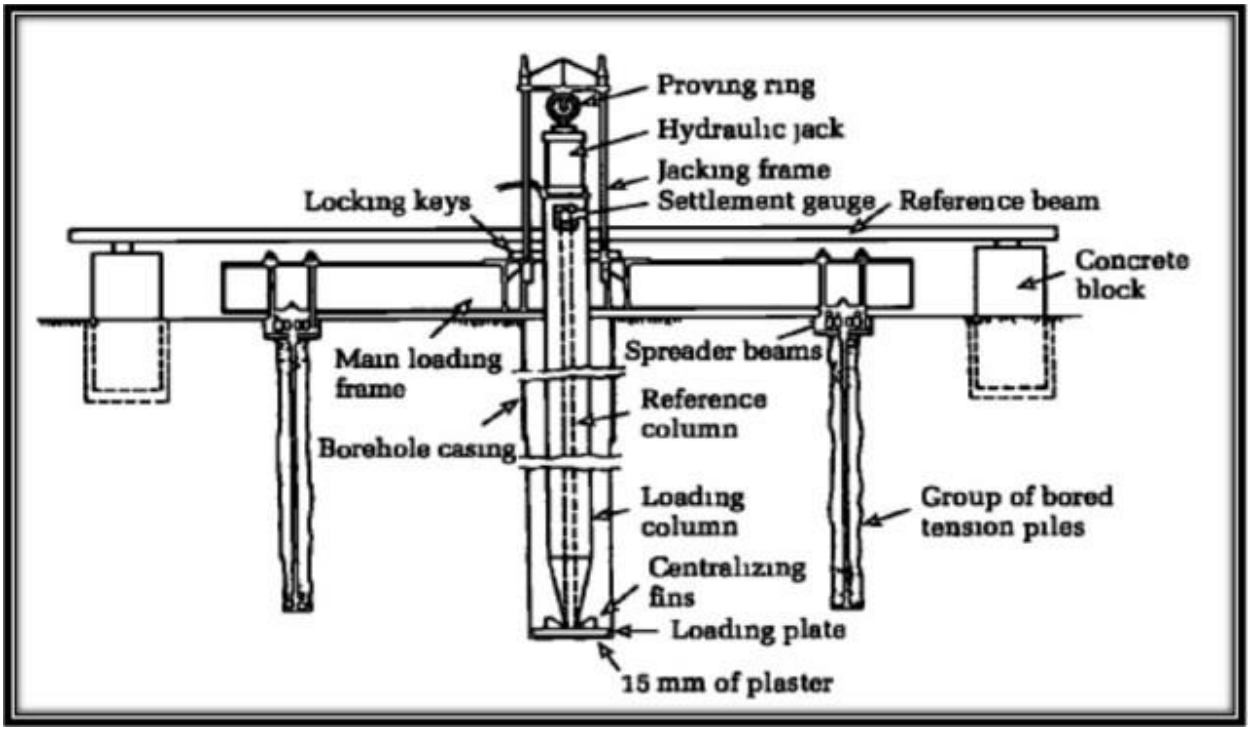


Fig-1 (Plate Load Test Setup)

PLATE LOAD TEST OBSERVATION SHEET

Project name:

Site location:

Depth of testing:

Depth of water table:

Date of testing:

Load (kN)	Time	Settlement dial gauge -1			Settlement dial gauge - 2		
		Dial gauge reading	Settlement (mm)	Cumulative settlement	Dial gauge reading	Settlement (mm)	Cumulative settlement

Fig-2 (PLT Observation Sheet)

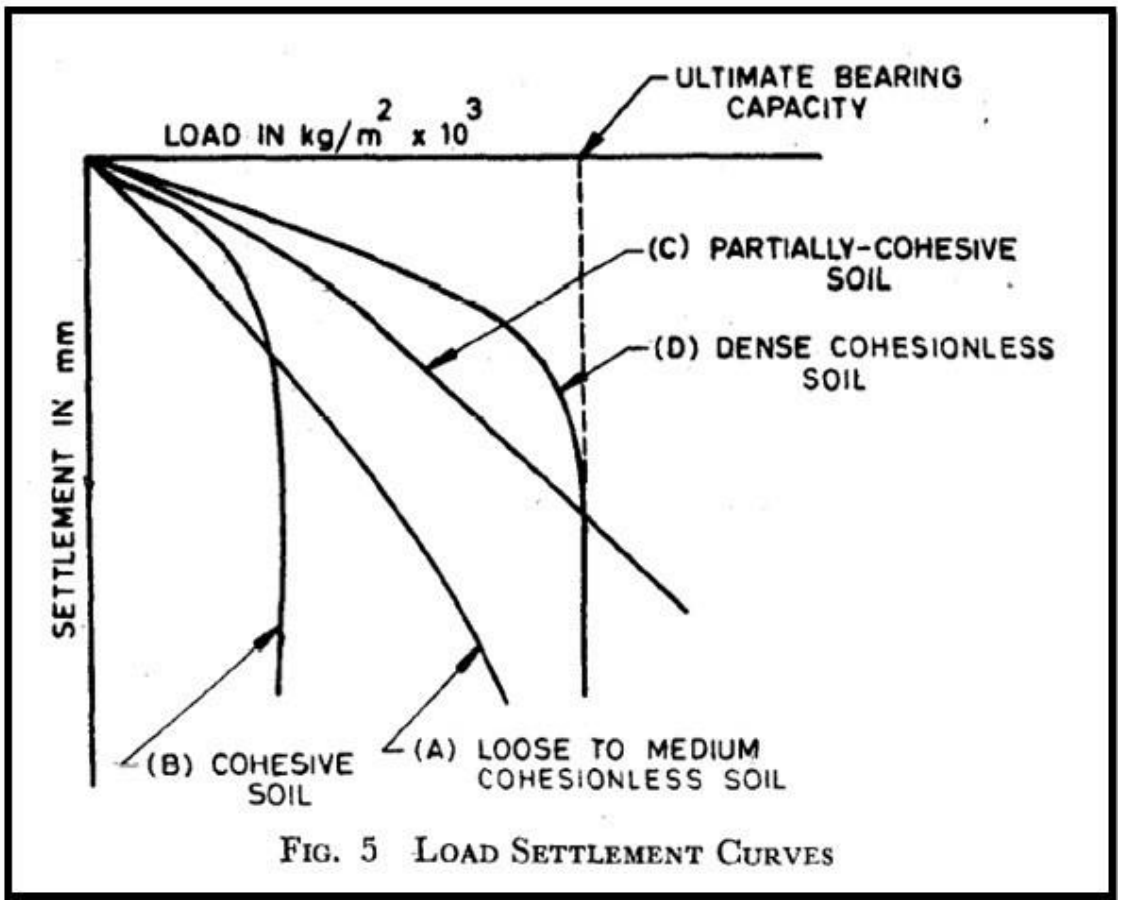

ULTIMATE BEARING CAPACITY
LOAD IN kg/m² x 10³
(C) PARTIALLY-COHESIVE SOIL
(D) DENSE COHESIONLESS SOIL
SETTLEMENT IN mm
(B) COHESIVE SOIL
(A) LOOSE TO MEDIUM COHESIONLESS SOIL
FIG. 5 LOAD SETTLEMENT CURVES

Fig-3 (PLT load-settlement curve)

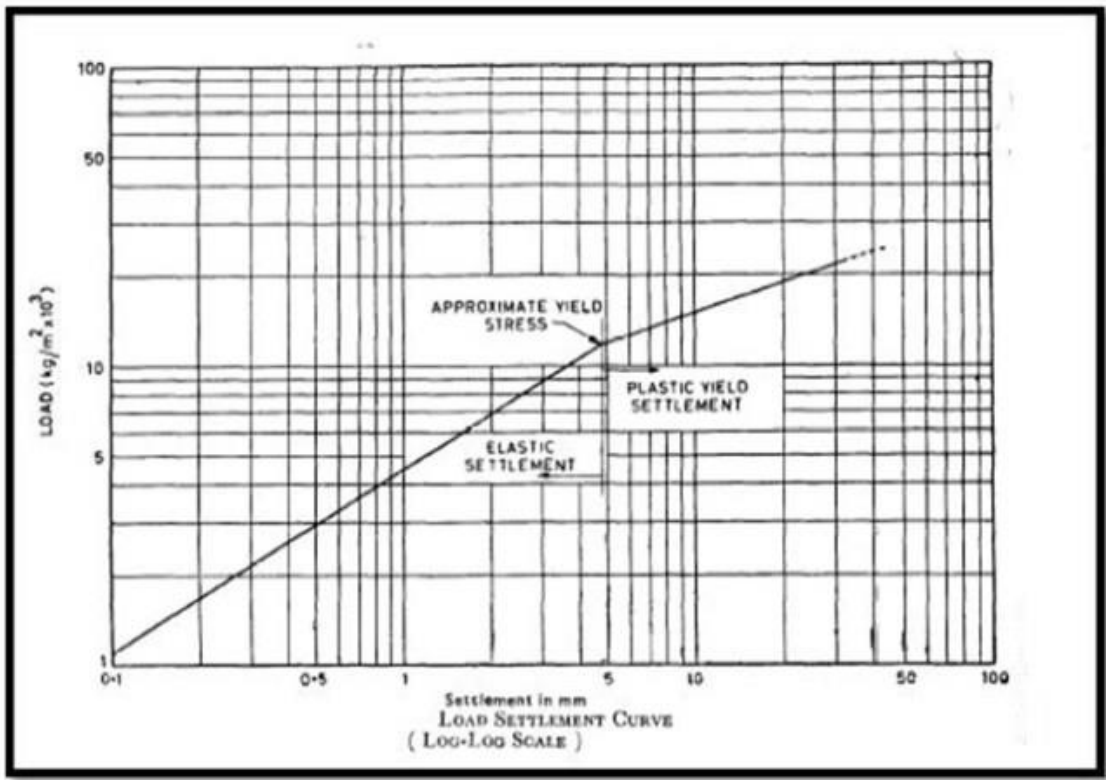


Fig-4 (PLT load-settlement logarithmic curve)

Also read the post on **uncertainties involved in plate load test.**

Also Read: How to Calculate Bearing Capacity of Soil From Plate Load Test

CONSISTENCY OF STANDARD CEMENT PASTE (IS: 4031-Part4-1988)

Overview

Standard consistency of a cement paste is defined as that consistency which will permit a vicat plunger having 10 mm dia and 50 mm length to penetrate to a depth of 33-35 mm from top of the mould.

Apparatus

Measuring Instruments

NAME	CAPACITY / RANGE / SIZE	ACCURACY / LEAST COUNT
Vicat apparatus	Should be made as per IS:5513	—
Balance	1000 g	1 g
Measuring cylinder	100 ml	1 ml

Other accessories Tray, glass plate

Vicat Apparatus

Environmental Condition

Temperature	27 ± 2^0 C
Humidity	65 ± 5 %

Procedure

1. Take 400 g of cement and place it in the enameled tray.
2. Mix about 25% water by weight of dry cement thoroughly to get a cement paste. Total time taken to obtain thoroughly mixed water cement paste i.e. “Gauging time” should not be more than 3 to 5 minutes.
3. Fill the vicat mould, resting upon a glass plate, with this cement paste.
4. After filling the mould completely, smoothen the surface of the paste, making it level with top of the mould.
5. Place the whole assembly(i.e. mould + cement paste + glass plate) under the rod bearing plunger.
6. Lower the plunger gently so as to touch the surface of the test block and quickly release the plunger allowing it to sink into the paste.
7. Measure the depth of penetration and record it.
8. Prepare trial pastes with varying percentages of water content and follow the steps (2 to 7) as described above, until the depth of penetration becomes 33 to 35 mm.

Calculation

Calculate percentage of water (P) by weight of dry cement required to prepare cement paste of standard consistency by following formula, and express it to the first place of decimal.

$$P = \frac{W}{C} \times 100$$

Where,
W=Quantity of water added
C=Quantity of cement used

Precautions

- Gauging time should be strictly observed
- Room temperature should be well maintained as per test requirement.
- All apparatus used should be clean.
- The experiment should be performed away from vibrations and other disturbances.

Technical Discussion

- This test helps to determine water content for other tests like initial and final setting time, soundness & compressive strength.

NAME OF TEST	AMOUNT OF WATER REQUIRED
Soundness (Le-chatelier method)	**0.78 P** (P=Consistency of standard cement paste)
Setting time	**0.85 P** (P=Consistency of standard cement paste)
Compressive strength	$(\frac{P}{4}+3)\%$ of combined mass of cement and sand.

- Consistency refers to the relative mobility of a freshly mixed cement paste or mortar or its ability to flow. For a mortar the standard consistency is measured by flow table test.
- Generally the normal consistency for OPC ranges from 26 to 33%.

Test Standard Reference

- IS:4031(Part 4):1988-Methods of physical tests for hydraulic cement (Determination of consistency of standard cement paste)

INITIAL & FINAL SETTING TIME (IS: 4031-Part 5-1988)

Overview

Initial setting time is that time period between the time water is added to cement and time at which 1 mm square section needle fails to penetrate the cement paste, placed in the Vicat's mould 5 mm to 7 mm from the bottom of the mould.

Final setting time is that time period between the time water is added to cement and the time at which 1 mm needle makes an impression on the paste in the mould but 5 mm attachment does not make any impression.

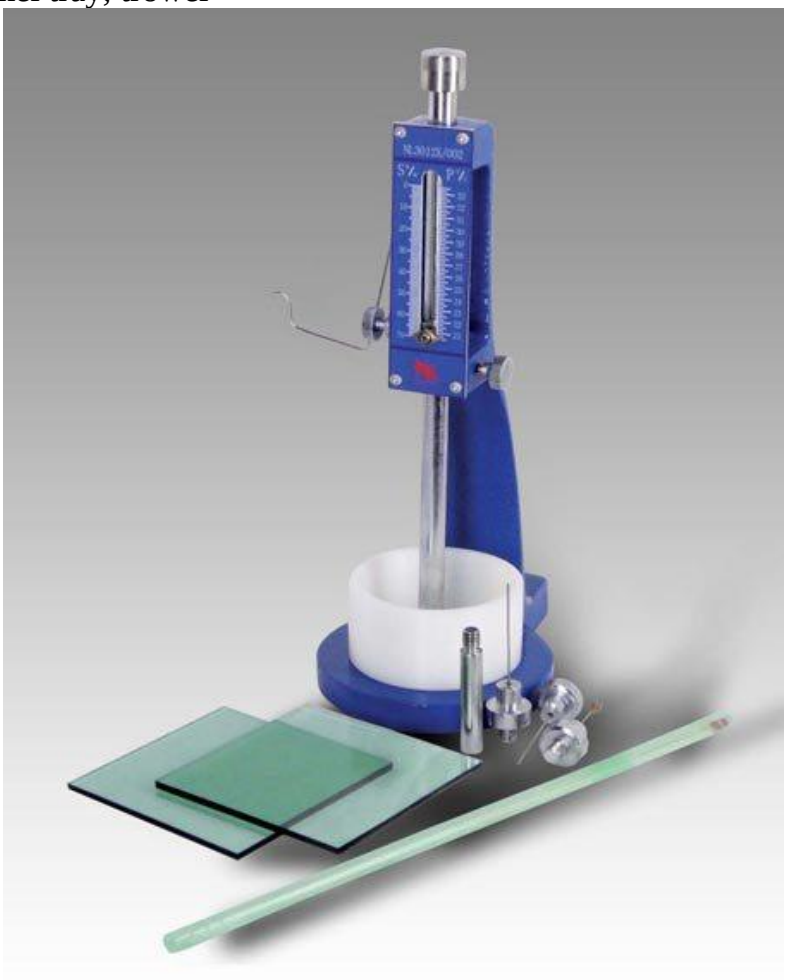
Apparatus

Measuring instruments

NAME	CAPACITY / RANGE / SIZE	ACCURACY / LEAST COUNT
Vicat apparatus	Should be made as per IS:5513	—
Balance	1000 g	1 g
Measuring cylinder	100 ml	1 ml
Stop watch	30 min.	0.2 sec

Other apparatus

Glass plate, enamel tray, trowel



Vicat Apparatus

Environmental Condition

Temperature	27 ± 2^0 C
Relative Humidity	90 % (min)

Procedure

(a)Test Block Preparation

1. Before commencing setting time test, do the consistency test to obtain the water required to give the paste normal consistency (P).
2. Take 400 g of cement and prepare a neat cement paste with 0.85P of water by weight of cement.
3. Gauge time is kept between 3 to 5 minutes. Start the stop watch at the instant when the water is added to the cement. Record this time (t_1).
4. Fill the Vicat mould, resting on a glass plate, with the cement paste gauged as above. Fill the mould completely and smooth off the surface of the paste making it level with the top of the mould. The cement block thus prepared is called test block.

(b)Initial Setting Time

1. Place the test block confined in the mould and resting on the non-porous plate, under the rod bearing the needle.
2. Lower the needle gently until it comes in contact with the surface of test block and quick release, allowing it to penetrate into the test block.
3. In the beginning the needle completely pierces the test block. Repeat this procedure i.e. quickly releasing the needle after every 2 minutes till the needle fails to pierce the block for about 5 mm measured from the bottom of the mould. Note this time (t_2).

(c)Final Setting Time

1. For determining the final setting time, replace the needle of the Vicat's apparatus by the needle with an annular attachment.
2. The cement is considered finally set when upon applying the final setting needle gently to the surface of the test block; the needle makes an impression thereon, while the attachment fails to do so. Record this time (t_3).

Calculation

Initial setting time=t_2-t_1

Final setting time=t_3-t_1,

Where,

t_1=Time at which water is first added to cement

t_2=Time when needle fails to penetrate 5 mm to 7 mm from bottom of the mould

t_3=Time when the needle makes an impression but the attachment fails to do so.

Precautions

- Release the initial and final setting time needles gently.
- The experiment should be performed away from vibration and other disturbances.
- Needle should be cleaned every time it is used.
- Position of the mould should be shifted slightly after each penetration to avoid penetration at the same place.
- Test should be performed at the specified environmental conditions.

Standard Specification

Type/Name Of Cement	Referenced Indian Stanadard	Initial Setting Time, mints (min.)	Final Setting Time, mints (max.)
OPC(33)	IS:269	30	600
OPC(43)	IS:8112	30	600
OPC(53)	IS:12269	30	600
SRC	IS:12330	30	600
PPC	IS:1489,P1	30	600
RHPC	IS:8041	30	600
PSC	IS:455	30	600
High alumina	IS:6452	30	600
Super sulphated	IS:6909	30	600
Low heat	IS:12600	60	600
Masonry cement	IS:3466	90	1440
IRS-T-40	Railway	60	600

Technical Discussion

- It is essential that cement set neither too rapidly nor too slowly. In the first case there might be insufficient time to transport and place the concrete before it becomes too rigid. In the second case too long a setting period tends to slow up the work unduly, also it might postpone the actual use of the structure because of inadequate strength at the desired age.
- Setting should not be confused with hardening, which refers to the gain in mechanical strength after the certain degree of resistance to the penetration of a special attachment pressed into it.
- Setting time is the time required for stiffening of cement paste to a defined consistency.
- Indirectly related to the initial chemical reaction of cement with water to form aluminum-silicate compound.
- Initial setting time is the time when the paste starts losing its plasticity.
- Initial setting time test is important for transportation, placing and compaction of cement concrete.
- Initial setting time duration is required to delay the process of hydration or hardening.
- Final setting time is the time when the paste completely loses its plasticity.
- It is the time taken for the cement paste or cement concrete to harden sufficiently and attain the shape of the mould in which it is cast.
- Determination of final setting time period facilitates safe removal of scaffolding or form.
- During this period of time primary chemical reaction of cement with water is almost completed.

Test Standard Reference

- IS:4031(Part 5):1988-Methods of physical tests for hydraulic cement (Determination of initial and final setting times)

SPECIFIC GRAVITY & WATER ABSORPTION OF AGGREGATE (IS: 2386-Part 3-1963)

Objective

For determination of specific gravity & water absorption of aggregates.

Reference Standards

IS: 2386 (Part 3) – 1963 – Method of test for aggregates for concrete (Part I) Particle size and shape.

Equipment & Apparatus

- Wire basket
- Oven (300^0c)
- Container for filling water and suspending the basket
- An air tight container
- Balance[0-10 kg]
- Shallow tray & absorbent clothes.

Preparation of sample

The sample to be tested is separated from the bulk by quartering or by using sample divider.

Procedure

1. About 2kg of the aggregate sample is washed thoroughly to remove fines, drained and then placed in the wire basket and immersed in distilled water at a temperature between 22 to 32^0C with a cover of at least 50 mm of water above the top of the basket
2. Immediately after the immersion the entrapped air is removed from the sample by lifting the basket containing it 25 mm above the base of the tank and allowing it to drop 25 times at the rate of about one drop per second. The basket and the aggregate should remain completely immersed in water for a period of 24±0.5 hours afterwards.
3. The basket and the sample are then weighed while suspended in water at a temperature of 22 to 32^0C. The weight is noted while suspended in water (W_1) g.
4. The basket and the aggregate are then removed from water and allowed to drain for a few minutes, after which the aggregates are transferred to one of the dry absorbent clothes.
5. The empty basket is then returned to the tank of water, jolted 25 times and weights in water (W_2) g.
6. The aggregates placed in the dry absorbent clothes are surface dried till no further moisture could be removed by this clothe.
7. Then the aggregate is transferred to the second dry cloth spread in a single layer, covered and allowed to dry for at least 10 minutes until the aggregates are completely surface dry. 10 to 60 minutes drying may be needed. The surface dried aggregate is then weighed W_3 g.
8. The aggregate is placed in a shallow tray and kept in an oven maintained at a temperature of 110^0C for 24 hours. It is then removed from the oven, cooled in air tight container and weighed W_4 g.

Calculation

Weight of saturated aggregate suspended in water with basket = W_1 g
Weight of basket suspended in water = W_2 g
Weight of saturated aggregate in water = (W_1-W_2)g = W_s g
Weight of saturated surface dry aggregate in air = W_4 g
Weight of water equal to the volume of the aggregate = (W_3-W_s) g

$$\text{Specific gravity} = \frac{W_4}{W_3 - (W_1 - W_2)}$$

$$\text{Apparent sp.gravity} = \frac{W_4}{(W_4 - (W_1 - W_2))}$$

$$\text{Water absorption} = \frac{(W_3 - W_4)}{W_4} \times 100$$

SPECIFIC GRAVITY OF FINE AGGREGATE

Apparatues

1.A balance of capacity not less than 3kg ,readable and accurate to 0.5 gm and of such a type as to permit the weighing of the vessel containing the aggregate and water .
2.A well ventilated oven to maintain a temperature of 100ºC to 110ºC
3.Pyconometer of about 1 littre capacity having a metal conical screw top with a 6mm hole at its apex . The screw top shall be water tight .
4.a means supplying a current warm air .
5.A tray of area not less than 32cm².
6.An air tight container large enough to take the sample.
7.Filter papers and funnel.

Procedure

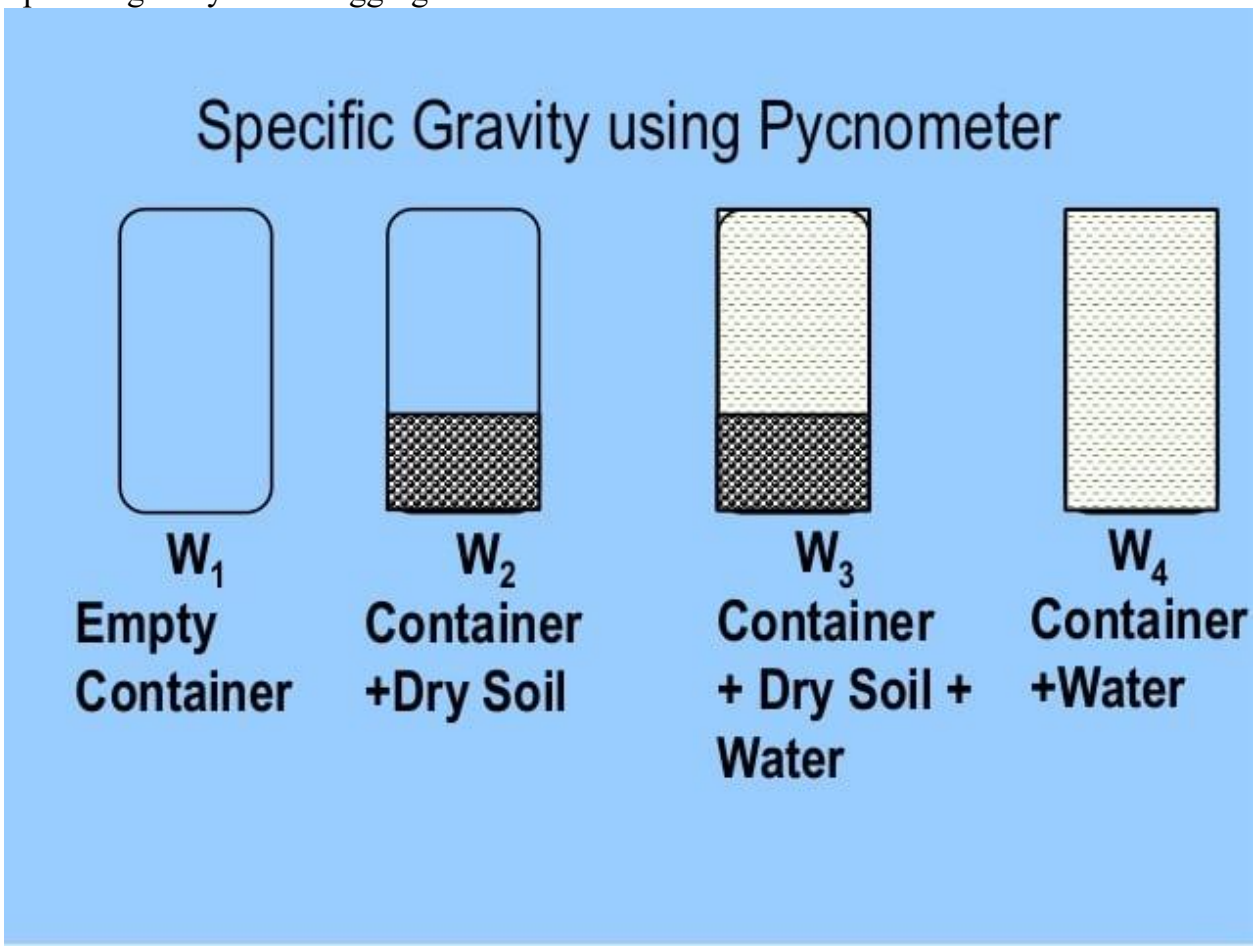
(I) Take about 500g of sample and place it in the pycnometer.
(II) Pour distilled water into it until it is full.
(III) Eliminate the entrapped air by rotating the pycnometer on its side ,the hole in the apex of the cone being covered with a finger.
(IV) Wipe out the outer surface of pycnometer and weigh it (W)
(V) Transfer the contents of the pycnometer into a tray , care being taken to ensure that all the aggregate is transferred .
(VI) Refill the pycnometer with distilled water to the same level .
(VII) Find out the weight (W1)
(VIII) drink water from the sample through a filter paper .
(IX) Place the sample in oven in a tray at a temperature of 100ºC to 110º C for 24±0.5 hours ,during which period ,it is stirred occasionally to facilitate drying .
(X) Cool the sample and weigh it (W2)

Calculation

Apparent specific gravity = (weight of dry sample/weight of equal volume of water)
= W2/(W2- (W-W2))

Result

Specific gravity of fine aggregate =……..



SPECIFIC GRAVITY TEST OF SOIL (IS-2720-PART-3-1980)

Objective

For determination of specific gravity of soil solids by pycnometer method.

Reference Standard

IS: 2720 (Part 4) – 1985 – Method of test for soil (Part 4-Grain size analysis)

Equipment & Apparatus

- Pycnometer
- Sieve(4.75 mm)
- Vacuum pump
- Oven
- Weighing balance
- Glass rod

Pycnometer Bottles

Preparation sample

After receiving the soil sample it is dried in oven at a temperature of 105 to 115^{0}C for a period of 16 to 24 hours.

Procedure

1. Dry the pycnometer and weigh it with its cap(W_1)
2. Take about 200 g to 300 g of oven dried soil passing through 4.75mm sieve into the pycnometer and weigh again(W_2)
3. Add water to cover the soil and screw on the cap.
4. Shake the pycnometer well and connect it to the vaccum pump to remove entrapped air for about 10 to 20 minutes.
5. After the air has been removed, fill the pycnometer with water and weigh it (W_3).
6. Clean the pycnometer by washing thoroughly.
7. Fill the cleaned pycnometer completely with water upto its top with cap screw on.
8. Weigh the pycnometer after drying it on the outside thoroughly(W_4).

Calculation

The Specific gravity of soil solids (Gs) is calculated using the following equation.

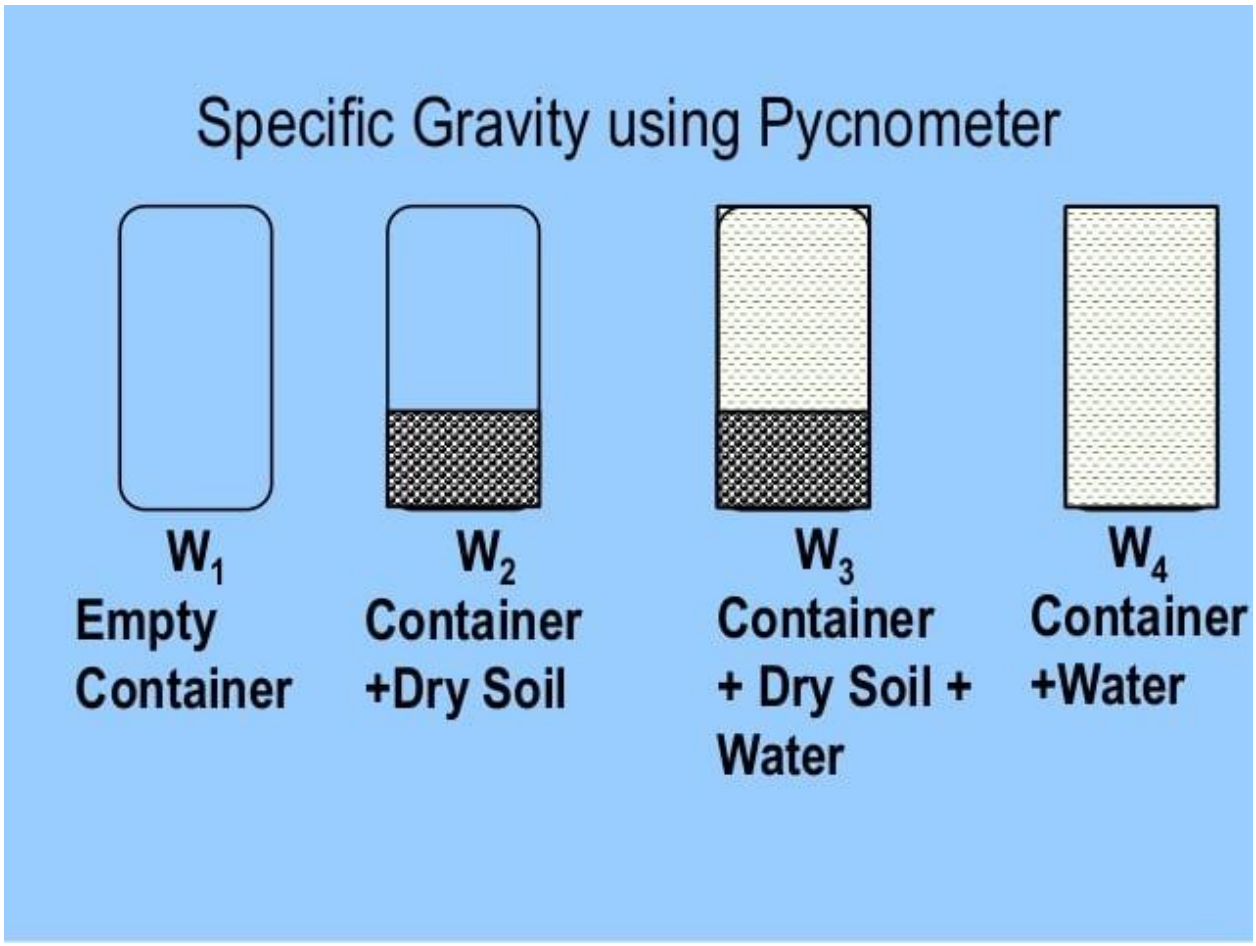
$$\text{Sp.Gravity(Gs)} = \frac{(W_2 - W_1)}{((W_2 - W_1) - (W_3 - W_4))}$$

Where

W_1=Empty weight of pycnometer
W_2=Weight of pycnometer + oven dry soil
W_3=Weight of pycnometer + oven dry soil + water
W_4=Weight of pycnometer + water full

Report

The result of the specific gravity test is reported to the nearest two digits after decimal.



BULK DENSITY VOIDS FINE ANDCOARSE AGGREGATE

Objective

Determination of unit weight or bulk density and void of aggregates.

Equipments

Name	Capacity
1. Balance	Sensitive to 0.5% of weight of material
2. Cylindrical metal measure	Of 3 litre capacity (for fine aggregate) Of 15 litre capacity (for aggregate upto 40mm) Of 30 litre capacity
3. Tamping rod	16 mm dia. and 60 cm long

cylindrical metal measure used for bulk density and void test of aggregate

Sample Preparation

- Take the required amount of test sample form the bulk sample using any sample reduction method.
- The test is normally carried out on dry material, but when bulking tests are required, material with a given percentage of moisture may be used.

A. Procedure for Compacted Bulk Density

1. Measure the volume of the cylindrical metal measure by pouring water into the metal measure and record the volume "V" in litre.
2. Fill the cylindrical metal measure about one-third full with thoroughly mixed aggregate and tamp it 25 times using tamping bar.
3. Add another layer of one-third volume of aggregate in the metal measure and give another 25 strokes of tamping bar.
4. Finally fill aggregate in the metal measure to over-flowing and tamp it 25 times.
5. Remove the surplus aggregate using the tamping rod as a straightedge.
6. Determine the weight of the aggregate in the measure and record that weight "W" in kg.

Calculation for Compacted Bulk Density

Compacted unit weight or bulk density = W/V

Where,

W = Weight of compacted aggregate in cylindrical metal measure, kg

V = Volume of cylindrical metal measure, litre

Calculation of Voids

The percentage of voids is calculated as follows
Percentage of voids = [(G – ϒ)/G]*100
Where
G = Specific gravity of the aggregate
ϒ = Bulk density in kg/litre

B. Procedure for Loose Bulk Density

1. Measure the volume of the cylindrical metal measure by pouring water into the metal measure and record the volume "V" in litre.
2. Fill the cylindrical measure to overflowing by means of a shovel or scoop, the aggregate being discharged from a height not exceeding 5 cm above the top of the measure
3. Level the top surface of the aggregate in the metal measure, with a straightedge or tamping bar.
4. Determine the weight of the aggregate in the measure and record the weight "W" in kg.

Calculation for Loose Bulk Density

Loose unit weight or bulk density = W/V
Where,
W = Weight of loose aggregate in cylindrical metal measure, kg
V = Volume of cylindrical metal measure, litre

Calculation of Voids

The percentage of voids is calculated as follows
Percentage of voids = [(G – ϒ)/G]*100
Where
G = Specific gravity of the aggregate
ϒ = Bulk density in kg/litre

Result

The bulk density is reported in kg/litre to the nearest 0.01 kg
The percentage of voids is reported to the nearest whole number.
Mention whether the aggregate is
(a) oven dry,
(b) saturated and surface dry or
(c) with a given percentage of moisture.

Using a Desiccator

Purpose:

The desiccator is used to store dried samples in a dry atmosphere. It should not be used to dry an object, but to maintain an already dried object indefinitely in a dry condition.

Usage:

1. To open - slide lid horizontally across the top to one side until it comes off. Use one hand to hold the bottom of the desiccator while using the other hand to grasp the knob.
2. To close - place lid partly on the top and slide across until desiccator is completely closed and then rotate lid gently in both directions.
3. Do not attempt to lift lid off vertically.
4. Make sure the lid has enough grease around the ground glass rim - if necessary, spread Vaseline uniformly on the rim. When the lid is properly seated, the greased rim will appear as shown in Figure 2.
5. If the desiccant appears wet or clumpy, it probably needs to be replaced with new dessicant. It is helpful to have a small amount of indicating desiccant present. When the color changes to pink, the desiccant should be replaced.
6. Desiccants should be handled in the hood and added carefully, wearing goggles and lab coat. Desiccant should not coat the sides or plate of the desiccator.

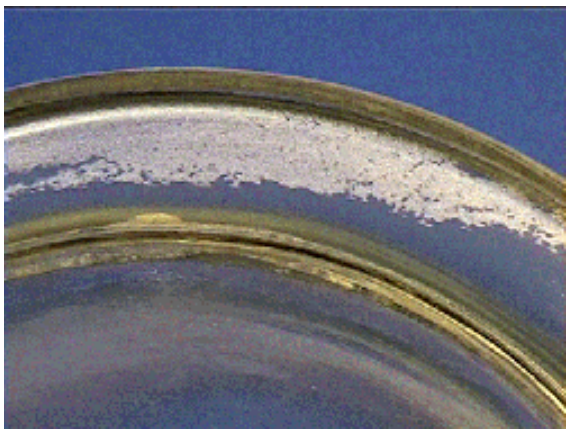


Figure 1. Improperly sealed desiccator. Note that the rim is clear.

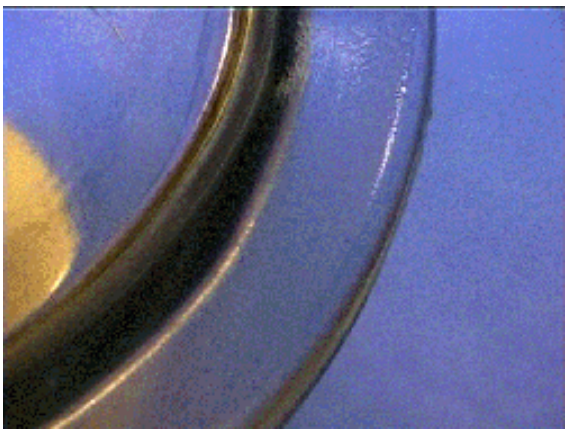


Figure 1. Properly sealed desiccator. Note the cloudiness along the rim.

BITUMEN CONTENT

Purpose

The test determines the bitumen content in the bituminous mix by cold solvent extraction.

Apparatus & Solvent

- Centrifuge apparatus
- Trichloroethylene

Centrifuge apparatus used for binder content test of bituminous mix

Procedure

1. Take a representative sample of about 500 g, weigh it exactly and place it in the bowl of the extraction apparatus (W_1).
2. Cover the sample with commercial grade trichloroethylene.
3. Let the mixture stand for about one hour before starting the centrifugal machine.
4. Weigh the dried filter ring and then fit it around the edge of the bowl. Clamp the cover of the bowl tightly.
5. Place a beaker under the drain to collect the extract.
6. The machine is revolved slowly and then gradually the speed is increased to a maximum of 3600 rpm. The speed is maintained till the solvent ceases to flow from the drain.
7. The machine is allowed to stop, 200 ml of solvent is added and the above procedure is repeated. A number of 200 ml solvent additions (not less than three) are used till the extract is clear and not darker than a light straw colour.
8. Remove the fitter ring from the bowl, dry it first in the air and then in the oven at 115^0C to a constant weight, and weigh it.
   Collect back the fine material that might have passed through the filter, by centrifuging. Wash and dry the material to a constant weight, as before.

Calculation

Calculate the percentage of binder in the bituminous mix sample as follows:

Percentage of Binder = $[W_1 – (W_2 + W_3 + W_4) /W_1] \times 100$

Where

W_1 = Weight of the sample, g

W_2 = Weight of the sample after extraction, g

W_3 = Weight of the fine material recovered from the extract, g

W_4 = Increase in weight of filter ring, g

Record all the test data in a form as shown below.

Percentage of Binder

Sl.No.	Observations	1	2	3
1.	Wt. of mix taken before extraction (W_1)			
2.	Wt. of filter paper before extraction (B)			
3.	Wt. of mix after extraction (W_2)			
4.	Wt. of filter paper after extraction (D)			
5.	Wt. of filler collected from extract after allowing for setting (W_3)			
6.	Wt. of filler collected in filter paper (B-D) = W_3			
7.	Wt. of Aggregate + filler collected after extraction = $W_2 + W_3 + W_4$			
8.	Percentage of Bitumen (in the mix) $(W_1-(W_2+W_3+W_4))*100/W_1$			

Sample form used to record data of bitumen content test of a bituminous mix

SOFTENING POINT OF BITUMEN (IS:1205:1978)

Ring & ball aparatus

Objective

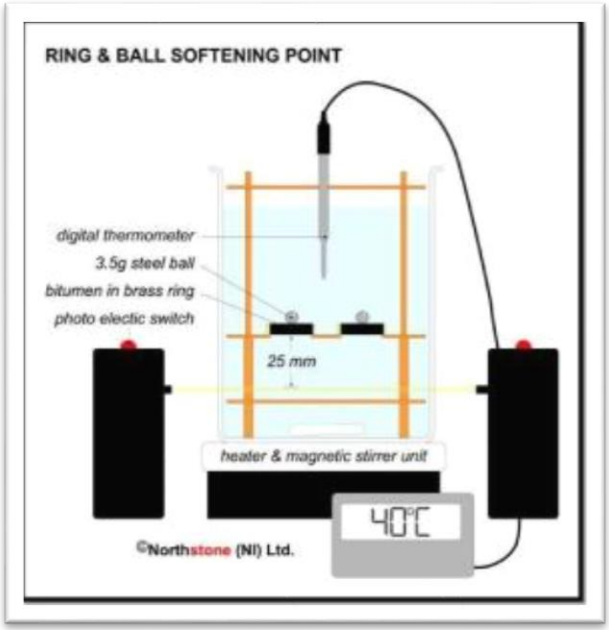
For determination of softening point of a given bitumen.

Reference Standards

IS : 1205-1978-Indian standard methods for testing tar and bituminious materials (Determination of softening point)

Equipment & Apparatus

- Ring and Ball apparatus, Steel balls, Brass rings,
- Ball guide, Support, Thermometer, Bath with stirrer



Procedure

1. Sample material is heated to a temperature between 75° and 100°C above the approximate softening point until it is completely fluid and is poured in heated rings placed on the metal plate.
2. To avoid sticking of the bitumen to metal plate, coating is done to this with a solution of glycerin and dextrin.
3. After cooling the rings in air for 30 minutes, the excess bitumen is trimmed and rings are placed in the support.
4. At this time the temperature of distilled water is kept at 5°C. This temperature IS maintained for 15 minutes after which the balls are placed in position.
5. Then the temperature of water is raised at uniform rate of 5°C per minute with a controlled heating unit, until the bitumen softens and touches the bottom plate by sinking of balls. At least two observations are made. For material whose softening point is above 80°C, glycerin is used for heating medium and the starting temperature is 35°C instead of 5°C.

Record /Reports

The temperature at the instant when each of the ball and sample touches the bottom plate of support is recorded as softening point value.An average value of two tests is reported as softening point value.

PENETRATION VALUE OF BITUMEN (IS:1203-1978)

Objective

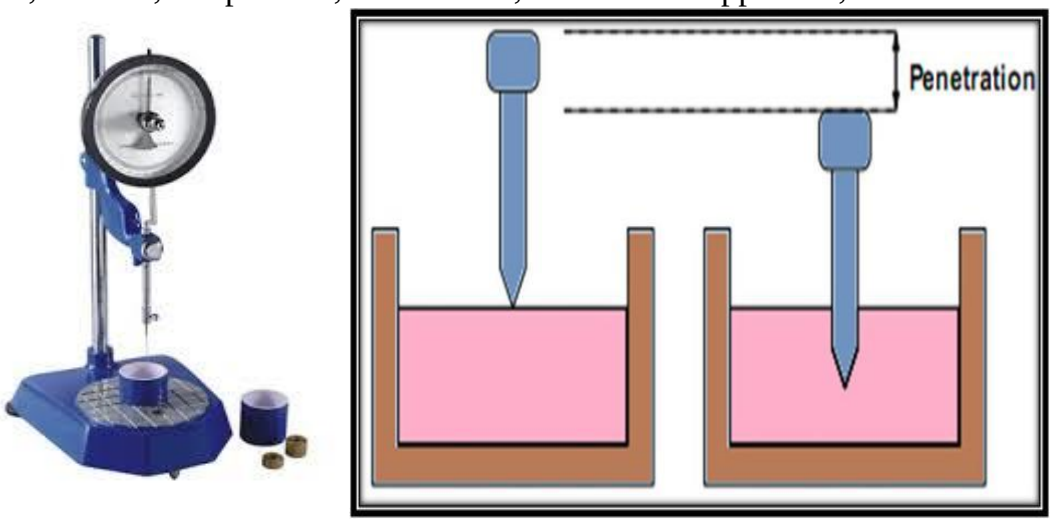
To determinate the penetration of bitumen.

Reference Standard

IS: 1203-1978-Indian standard methods for testing tar and bituminious materials (Determination of penetration)

Equipment & Apparatus

- Container, Needle, Stop watch, Water bath, Penetration apparatus, Thermometer



Penetration Test

Procedure

1. The bitumen is softened to a paving consistency between 75^0 C and 100^0C above the approximate temp at which bitumen softens.
2. The sample material is thoroughly stirred to make it homogeneous and free from air bubbles and water.
3. The sample containers are cooled in atmosphere of temperature not lower than 13°C for one hour. Then they are placed in temperature controlled water bath at a temperature of 25°C for a Period of one hour.
4. The weight of needle, shaft and additional weight are checked. The total weight of this assembly should be 100 g.
5. Using the adjusting screw, the needle assembly is lowered and the tip of the needle is made to just touch the top surface of the sample.
6. The needle assembly is clamped in this position. The contact of the tip of the needle is checked using the mirror placed on the rear of the needle.
7. The initial reading of the penetrometer dial is either adjusted to zero or the initial reading is noted.
8. Then the needle is released by pressing a button and a stop watch is started. The needle is released exactly for a period of 5.0 secs.
9. At least 3 measurements are made on this sample by testing at distance of not less than 100 mm apart.

Calculation

The difference between the initial and final penetration readings are taken as the penetration value.

Report

The average penetration value of 3 tests of a given bitumen sample is reported.

DUCTILITY VALUE OF BITUMEN (IS:1208-1978)

Objective

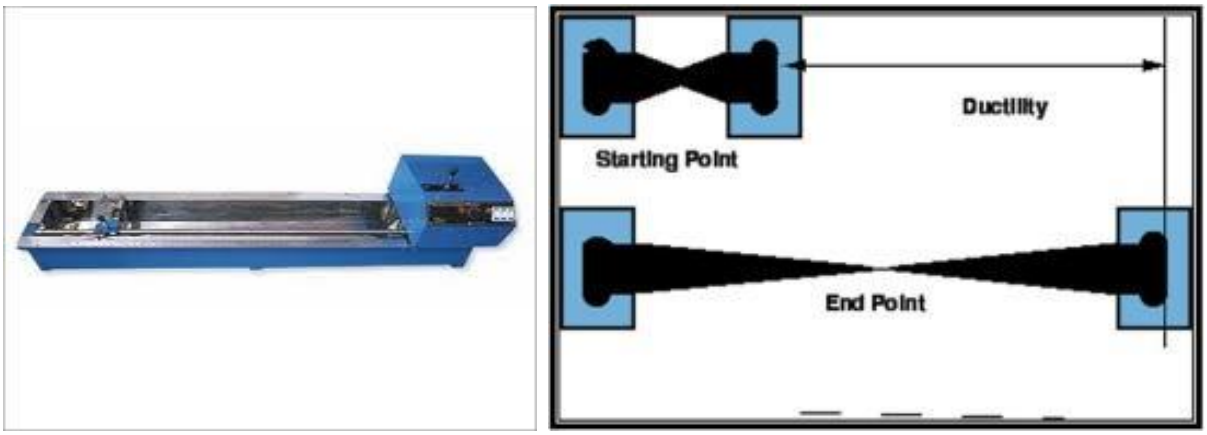
For determination of ductility of distillation residue a given bitumen.

Reference Standard

IS : 1208-1978- Indian standard methods for testing tar and bituminious materials (Determination of ductility)

Equipment & Apparatus

- Briquette mould,
- Ductility machine with water bath and a pulling device
- A putty knife
- Thermometer



Ductility test

Procedure

1. The bitumen sample is method to a pouring temperature (75°C to 100°C) and poured into the mould assembly and placed on a brass plate, where a solution of glycerin or soap solution is applied at all surfaces of briquette mould exposed to bitumen.
2. After the sample is poured to the mould, thirty to forty minutes the entire assembly is placed in a water bath at 27°C.
3. Then the sample is removed from the water bath maintained at 27°C and excess bitumen material is cutoff by leveling the surface using hot knife.
4. After trimming the specimen, the mould assembly containing sample is replaced in water bath maintained at 27°C for 85 to 95 minutes. Then the sides of mould are removed and the clips are carefully booked on the machine without causing any initial strain. Two or more specimens may be prepared in the moulds and clipped to the machine so as to conduct these test simultaneously.
5. The pointer is set to read zero. The machine is started and the two clips are thus pulled apart horizontally.
6. While the test is in operation, it is checked whether the sample is immersed in water at depth of at least 10 mm.

Reports

The distance at which the bitumen thread of each specimen breaks is recorded (in cm) to report as ductility value.The average penetration value of 3 tests of a given bitumen sample is reported.

Flash- and Fire Point Measurement

The flash point test can be summarized as a procedure in which a test specimen is introduced into a temperature-controlled test cup and an ignition source is applied to the vapors produced by the test specimen. The aim of the test is to determine whether the vapor/air mixture is flammable or at what temperature the vapor/air mixture is flammable.

There are many, slightly different, definitions of flash point. However, the following definition is widely used in standard test methods:

The lowest temperature of the test specimen, corrected to a barometric pressure of 101.3 kPa, at which the application of an ignition source causes the vapor of the test specimen to ignite momentarily and the flame to propagate across the surface of the liquid under the specified conditions of test.

It is important to realize that the value of the flash point is not a physical constant but is the result of a flash point test and is dependent on the apparatus and procedure used.

Flash point

can therefore only be defined in terms of a standard test method, and no general valid correlation can be guaranteed between results obtained by different test methods or with test apparatus different from that specified.

Fire point

may be considered as the lowest temperature of the liquid at which vapor combustion and burning commences. A fire point happens when an ignition source is applied and the heat produced is self-sustaining, as it supplies enough vapors to combine with air and burn even after the removal of the ignition source.

The flammability of a substance is therefore characterized by:

- The conditions under which a substance can be ignited and those under which it continues to burn – known respectively as the FLASH POINT and FIRE POINT.
- The concentration range over which the vapor/oxidant mixture is flammable, i.e. the upper and lower flammability limits. These limits vary depending on the oxidant, pressure and the minimum oxygen concentration required for the combustion reaction.

Due to the importance of flash point test results for both safety and regulatory purposes, the test method identification should always be included with the test result.

Why are flash point tests required?

The fundamental reason for the requirement of flash point measurements is to assess the safety hazard of a liquid or semi-solid with regard to its flammability and then classify the liquid into a group. The lower the flash point temperature, the greater the risk. This classification is then used to warn of a risk and to enable the correct precautions to be taken when using, storing or transporting the liquid.

Specifications quote flash point values for quality control purposes as well as for controlling the flammability risk. A change in flash point can indicate the presence of potentially dangerous volatile contaminants or the adulteration of one product by another.

The classification of chemicals including petroleum products helps to identify the hazards of a substance or preparation. It is important that the classification of the hazard is correct, otherwise the label, safety
data sheet and the packaging may be incorrectly assigned. This can have potentially serious consequences for the end user.
There are many health and safety legislations which require such classification:

- CPSC: United States Consumer Products Safety Commission
- DOT: United States Department of Transportation
- EPA: United States Environmental Protection Agency
- NFPA: National Fire Protection Agency
- OSHA: United States Occupational Safety and Health Administration
- UN: Class 3 Dangerous goods
- ADR: The European agreement concerning the international carriage of dangerous goods by road
- ECHA: European Chemicals Agency, guidance to regulation on classification, labelling and packaging (CLP) of substances and mixtures

The presence of contaminations can have a significant effect on the flash point, particularly if the contaminant is relatively more volatile. For example, pure ethylene glycol has a flash point of 111 °C. However, the flash point is reduced to 29 °C when acetaldehyde at a level of only 2 % is present.
Another common example would be ethanol; water addition has a significant effect on flammability.

% Ethanol in water	Approx. flash point in °C
100	13.0
90	14.5
75	20.5
50	23.5
25	31.5
10	47.5
5	61.5

For solvents which are immiscible in water, the flash point will be largely unaffected by the addition of water.

Which flash point method should be used?

If a flash point method has been specified in a product specification or regulation, then that method should be the first choice.
When testing specifically for contamination or contaminants, certain test methods and procedures are more appropriate than others. In general, an equilibrium test method is recommended for testing samples that may contain traces of volatile contaminants.
When selecting a flash point method for incorporation into a product specification or regulation, it is important that the product type is included in the scope of the test method and that the temperature range of the product is covered by the test method. If the product is not included in the scope then the test may be unsuitable for the product or the quoted precision may not apply.
When testing chemicals, mineral products or corrosive materials it is recommended to check that the test cup material is suitable and will not produce flammable gases or be damaged by any possible chemical reaction. Many flash point testers are available with stainless steel test cups.

Open or closed cup?

There are two general classes of flash point tests: open cup and closed cup.

CLA 5 – Automatic open-cup tester

The **open-cup** test was initially developed to assess the potential hazards of liquid spillage. An ignition source is passed horizontally over the surface of the liquid, while the cup and liquid are being heated, to test if the vapors 'flash'. If the test is repeated at increasing test specimen temperatures a point may be reached at which the specimen continues to burn without further application of the ignition source, this is the fire point.

The precision of open-cup tests is somewhat poorer than closed-cup tests as the vapors produced by heating the test specimen are free to escape to the atmosphere and are more affected by local conditions in the laboratory. When open-cup tests are carried out at temperatures above ambient the result is usually higher than a result from a closed-cup test due to the reduced concentration of vapors.

PMA 5 – Automatic closed-cup tester

The **closed-cup** test contains any vapors produced and essentially simulates the situation in which a potential source of ignition is accidentally introduced into a container. In this test a test specimen is introduced into a cup and a close-fitting lid is fitted to the top of the cup. The cup and test specimen is heated. Subsequently, apertures are opened in the lid to allow air into the cup and the ignition source to be dipped into the vapors to test for a flash.

The closed cup is mostly used in product specifications and regulations due to its better precision.

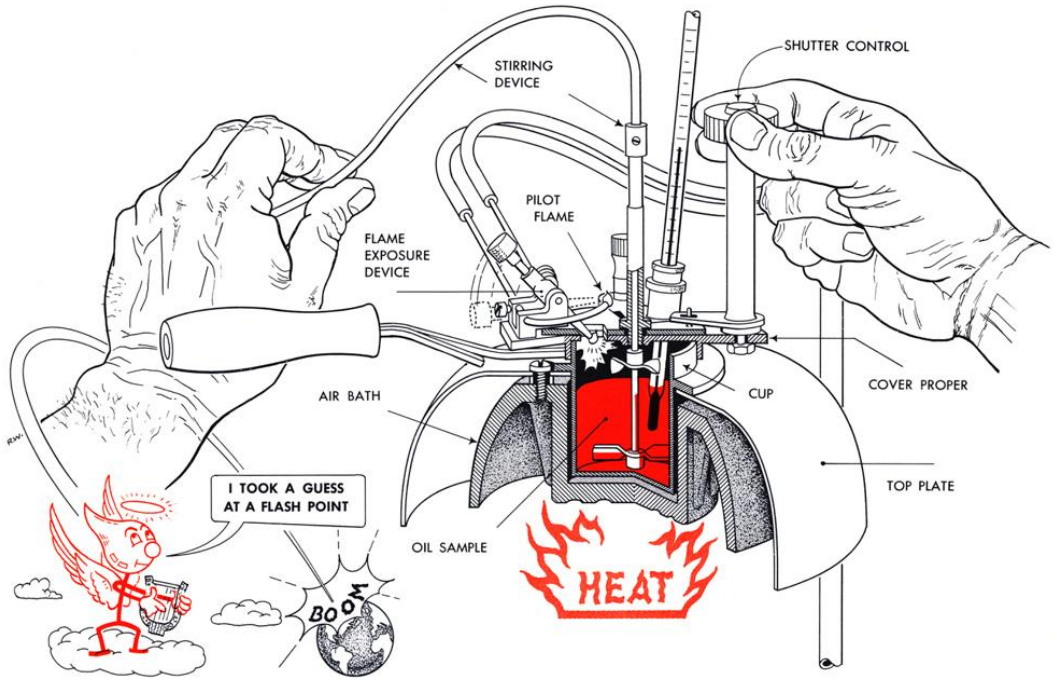
The following table shows the comparative flash points measured in open and closed cup apparatus for some common pure liquids.

Comparison of flash points measured in open- and closed-cup apparatus

Liquid	Flash point [°C]	
	Closed Cup	Open Cup
Acetic acid	40	43
Acetone	-17	-9
n-Butanol	29	44
Methanol	10	16
Toluene	4	7

Flash point automation

In a manual flash point test the operator is in control throughout the test, ensures that the temperature, stirring and ignition requirements are at all times and determines when and if a flash has occurred. This is why manual tests are the reference in cases of dispute.



Manual test apparatus

Source: Lubrication Engineers Manual, Lubricants Testing Laboratory, 1960 Copyright: National Tube Division, United States Steel Corporation

Automatic flash point testers conform to all the specified requirements of the manual test method, such as dimensions, heating rate and flash detection. However, the electronics, software and mechanics mimic the manual operations. This can significantly reduce operator time and involvement, greatly increasing laboratory efficiency.

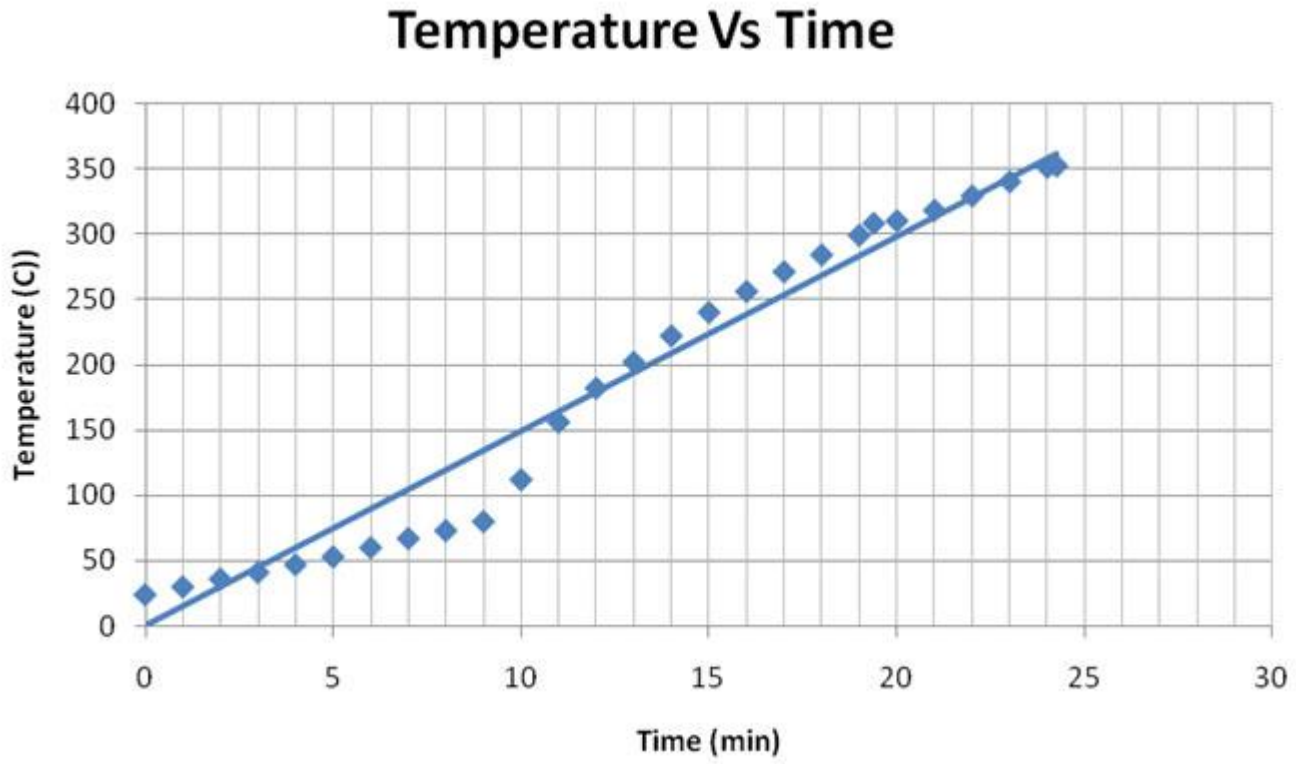
In general automatic instruments are accepted in test methods provided that the instrument can be shown to conform to the method requirements.

Correlation between methods

It is well-known that open-cup tests usually give higher flash point results than closed-cup tests for test temperatures above ambient. However, flash point methods employ different apparatus, heating and stirring rates, procedures and sample handling. All of these have an effect on relative biases, especially when the liquid is volatile or if volatile components are present. Therefore, it is not possible to claim correlation or a fixed relative bias between different test methods for all test samples.

OBSERVATIONS & RESULTS

Time (minutes)	Temperature (°C)	Remarks	Time (minutes)	Temperature (°C)	Remarks
0	24		13	202	
1	30		14	222	
2	36		15	240	
3	41		16	256	
4	47		17	271	
5	53		18	284	
6	60		19	299	
7	67		9:12	308	Flash Point
8	73		20	310	
9	80		21	318	
10	112		22	329	
11	156		23	340	
12	182		24	351	
			24.25	352	Fire Point



COMMENTS

The Experiment has been performed successfully and the results which we have got are showing that the flash point of the bitumen sample came out to be at 308° and time corresponding to this temperature was 9.12 minutes. Whereas the fire point was found out to be at temperature of 352° and the time corresponding to this temperature was 24.25 minutes. The trend line of the graph is showing the relationship between temperature and time.

MARSHALL STABILITY AND FLOW
Standard Test Procedures Manual

STP 204-11

SCOPE

Description of Test

This method covers the measurement of resistance to plastic flow of cylindrical specimens of asphalt mixtures loaded on the lateral surface by means of the Marshall apparatus. This method is for use with mixtures containing asphalt cement, asphalt cutback, and aggregate up to 25.4 mm maximum size.

Application of Test

The testing section of this method can also be used to obtain maximum load and flow for asphalt concrete specimens cored from pavements or prepared by STP 204-8, Preparation of Marshall Compaction Specimens.

Units of Measure

Stability is measured in Newtons. Flow is measured in mm.

APPARATUS AND MATERIALS

Equipment Required

Breaking Head - the breaking head shall consist of upper and lower cylindrical segments or test heads having an inside radius of curvature of 50.8 mm accurately machined. The lower segment shall be mounted on a base having two perpendicular guide rods or posts extending upward. Guide sleeves in the upper segment shall be in such a position as to direct the two segments together without appreciable binding or lose motion on the guide rods.

Loading Jack - the loading jack shall consist of a screw jack mounted in a testing frame and shall produce a uniform vertical movement of 50.8 mm/minute. An electric motor may be attached to the jacking mechanism.

Ring Dynamometer Assembly or Electronic Equivalent - one ring dynamometer of 2267 kg capacity and sensitivity of 4.536 kg up to 453.6 kg and 11.34 kg between 453.6 and 2267 kg shall be equipped with a micrometer dial. The micrometer dial shall be graduated in 0.0025 mm. Upper and lower ring dynamometer attachments are required

for fastening the ring dynamometer to the testing frame and transmitting the load to the breaking head.
Flowmeter - the flowmeter shall consist of a guide sleeve and a gauge. The activating pin of the gauge shall slide inside the guide sleeve with a slight amount of frictional resistance. The guide sleeve shall slide freely over the guide rod of the breaking head. The flowmeter gauge shall be adjusted to zero when placed in position on the breaking head when each individual test specimen is inserted between the breaking head segments.
Water Bath - the water bath shall be at least 152 mm deep and shall be thermostatically controlled so as to maintain the bath at 60 ± 1o C. The tank shall have a perforated false bottom or be equipped with a shelf for supporting specimens 51 mm above the bottom of the bath.
Air Bath - the air bath for asphalt cutback mixtures shall be thermostatically controlled and shall maintain the air temperature at 25 ± 1o C.

Materials Required

Samples may include cored specimens, field or lab prepared specimens.

Sample to be Tested

Density of the specimen is required to obtain the volume for a correlation ratio. Density can be determined as outlined in STP 204-21, DENSITY AND VOID CHARACTERISTICS.

PROCEDURE

Equipment Preparation

Thoroughly clean the guide rods and the inside surfaces of the test heads prior to making the test, and lubricate the guide rods so that the upper test head slides freely over them.

Sample Preparation

Samples will be prepared in accordance with STP 204-8, Preparation of Marshall Compaction Specimens or collected in accordance with STP 204-5, Asphalt Concrete Samples Obtained by Coring.

Test Procedure

Bring the specimens prepared with asphalt cement to the specified temperature by immersing in a water bath 30 minutes. Maintain the bath or oven temperature at 60 ± 1o C for asphalt cement specimens. Bring the specimens prepared with asphalt cutback to the specified temperature by placing them in the air bath for a minimum of 2 hours. Maintain the air bath temperature at 25 ± 1o C.
The testing head temperature shall be maintained between 20 to 38o C. Remove the specimen from the water bath, oven or air bath and place in the lower segment at the breaking head. Place the upper segment of the breaking head on the specimen and place the complete assembly in position on the testing machine. Place the flowmeter, where used, in position over one of the guide rods and adjust the flowmeter to zero while holding the sleeve firmly against the upper segment of the breaking head. Hold the
flowmeter sleeve firmly against the upper segment of the breaking head while the test load is being applied. Apply the load to the specimen by means of the constant rate of movement of the load jack or testing machine head of 50.8 mm/minute until the maximum load is reached and the load decreases as indicated by the dial. Record the maximum load noted on the testing machine or converted from the maximum micrometer dial reading. Release the flowmeter sleeve or note the micrometer dial reading, where used, the instant the maximum load begins to decrease. Note and record the indicated
flow value or equivalent units in mm if a micrometer dial is used to measure the flow. The elapsed time for the test from removal of the test specimen from the water bath to the maximum load determinations shall not exceed 30 seconds.

RESULTS & CALCULATIONS

Collection of Test Results

For specimens other than 63.5 mm in thickness correct the load by using the proper multiplying factor from Table 1. The reports shall include the following information:

a) Type of sample tested (lab sample or pavement core specimen). For core specimens the height of each test specimen in mm shall be reported.

b) Average maximum load in newtons, corrected when required.

c) Average flow value in millimeters, d) Test temperature

TABLE 1 - Stability Correlation Ratios*

Volume of Specimen (cm3)	Thickness of Specimen (mm)	Correlation Ratio
200 to 213	25.4	5.56
214 to 225	27.0	5.00
225 to 237	28.6	4.55
238 to 250	30.2	4.17
251 to 264	31.8	3.85
265 to 276	33.3	3.57
277 to 289	34.9	3.33
290 to 301	36.5	3.03
302 to 316	38.1	2.78
317 to 328	39.7	2.50
329 to 340	41.3	2.27
341 to 353	42.9	2.08
354 to 367	44.4	1.92
368 to 379	46.0	1.79
380 to 392	47.6	1.67
393 to 405	49.2	1.56
406 to 420	50.8	1.47
421 to 431	52.4	1.39
432 to 443	54.0	1.32
444 to 456	55.6	1.25
457 to 470	57.2	1.19
471 to 482	58.7	1.14
483 to 495	60.3	1.09
496 to 508	61.9	1.04
509 to 522	63.5	1.00
523 to 535	64.0	0.96
536 to 546	65.1	0.93
547 to 559	66.7	0.89
560 to 573	68.3	0.86
574 to 585	71.4	0.83
586 to 598	73.0	0.81
599 to 610	74.6	0.78
611 to 625	76.2	0.76

* The measured stability of a specimen multiplied by the ratio for the thickness of the specimen equals the corrected stability for a 63.5 mm specimen.

REPEATABILITY

At least 3 test specimens should be used and the individual results averaged. Repeatability shall be as outlined in ASTM D1559, Standard Test Method for Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus.